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ABSTRACT

This module is one of a series of teaching guides that cover diesel mechanics. The module contains 4 sections and 19 units. Section A--Orientation includes the following units: introduction to diesel mechanics and shop safety; basic shop tools; test equipment and service tools; fasteners; bearings; and seals. Section B--Engine Principles and Components includes: engine operating principles; cylinder head assembly; piston and connecting rod assemblies; camshafts, gear train, and engine timing; cylinder blocks and liners; and crankshafts and bearings. The topics covered in Section C--Auxiliary Systems are: lubricants and lubrication systems; coolants and cooling systems; air intake and exhaust systems; and engine brakes and retarders. Section D--Maintenance covers: preventive maintenance; troubleshooting and testing of engines; and tune-up and adjustment. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use in more than one lesson or class period. Instructional task analyses are also included. (SK)

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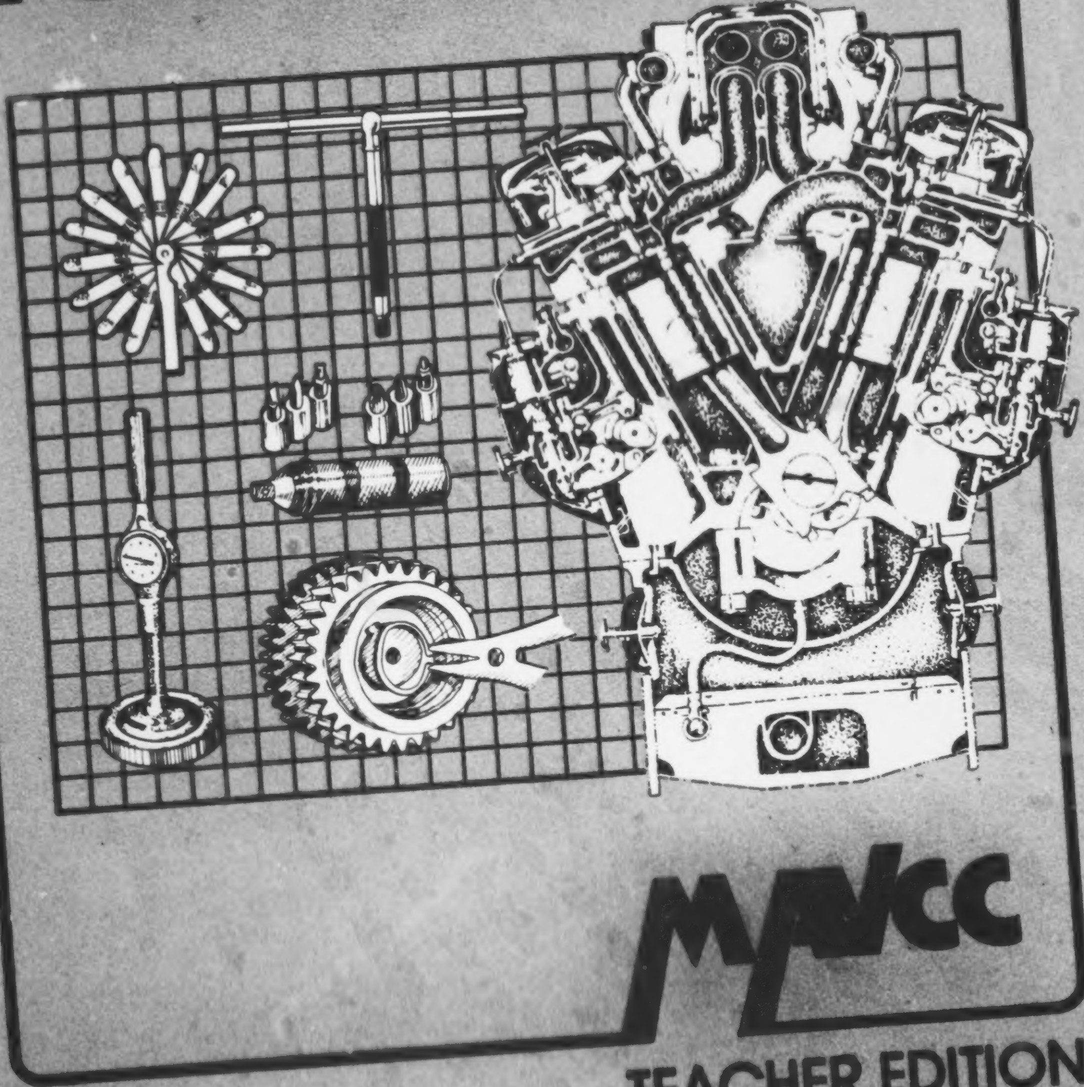

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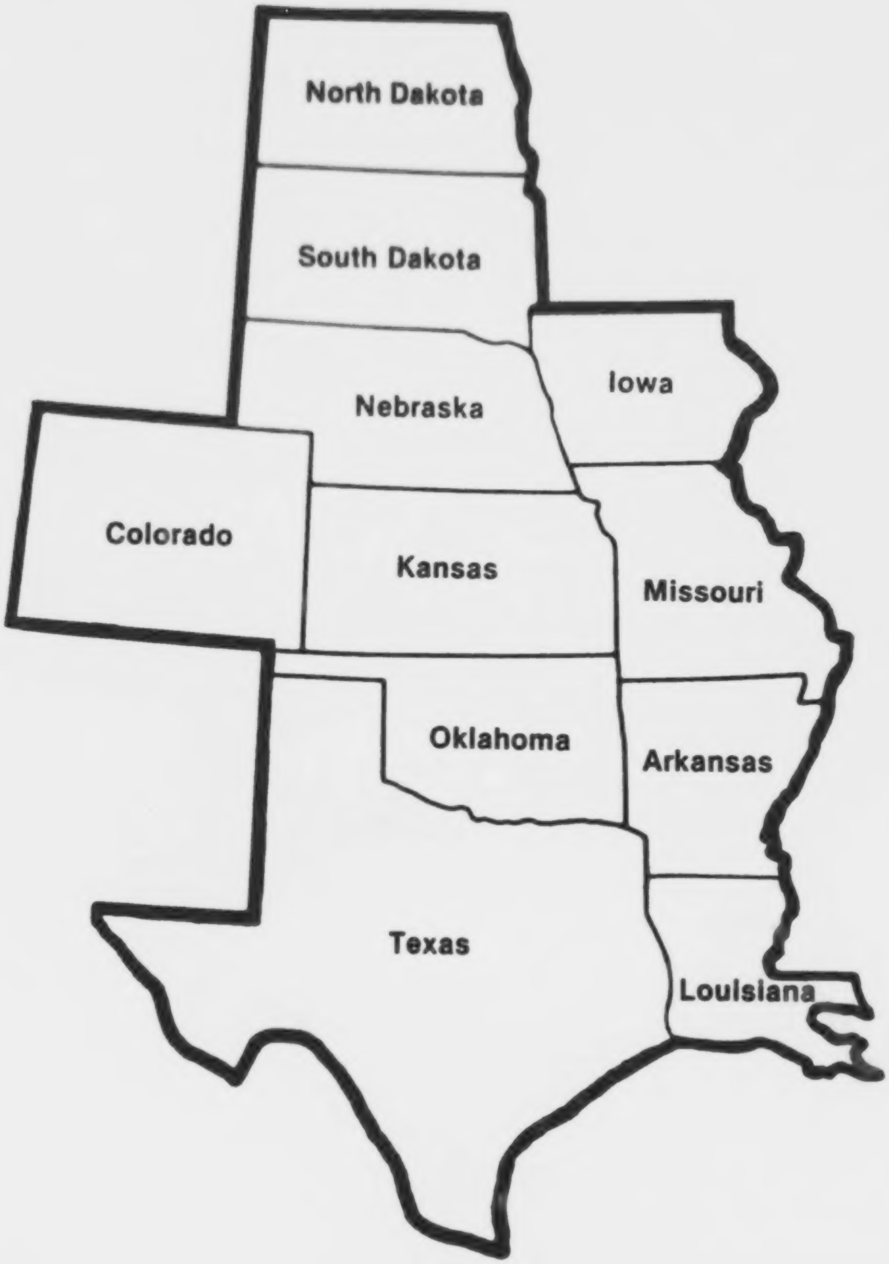
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DIESEL FUNDAMENTALS

Revised by

Elton Clark
Joe Mathis
Tom Sprinkle

Edited by

Ellen Beeby

Developed by

The Mid-America Vocational Curriculum Consortium, Inc.

Board of Directors

Harley Schlichting, Missouri, Chairman
Ron Mehrer, North Dakota, Vice Chairman
Joyce Sawatzky, Oklahoma, Parliamentarian
Jim Adams, Arkansas
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DIESEL FUNDAMENTALS

TABLE OF CONTENTS

Section A — Orientation

Unit I: Introduction to Diesel Mechanics and Shop Safety 1
Unit II: Basic Shop Tools 41
Unit III: Test Equipment and Service Tools 161
Unit IV: Fasteners 209
Unit V: Bearings 283
Unit VI: Seals 351

Section B — Engine Principles and Components

Unit I: Engine Operating Principles 1
Unit II: Cylinder Head Assembly 45
Unit III: Piston and Connecting Rod Assemblies 119
Unit IV: Camshafts, Gear Train, and Engine Timing 187
Unit V: Cylinder Blocks and Liners 263
Unit VI: Crankshafts and Bearings 317

Section C — Auxiliary Systems

Unit I: Lubricants and Lubrication Systems 1
Unit II: Coolants and Cooling Systems 49
Unit III: Air Intake and Exhaust Systems 99
Unit IV: Engine Brakes and Retarders 163

Section D — Maintenance

Unit I: Preventive Maintenance 1
Unit II: Troubleshooting and Testing of Engines 27
Unit III: Tune-Up and Adjustment 69

FOREWORD

Both the development and revision of instructional materials in diesel mechanics have been rewarding efforts because of the talented people who planned and wrote the materials. From the team of teachers, industry representatives, and trade and industrial staff members has come a series of texts which should offer diesel mechanics students an excellent opportunity for learning required skills.

The title of this introductory of the series, *Diesel Fundamentals* indicates that this book is dedicated to teaching the basic concepts related to employment in a diesel trade. Naturally, this book is designed to be used with other MAVCC books related to diesel. These include *Diesel Mechanics: Fuel Systems; Diesel Mechanics: Electrical Systems; Power Trains;* and *Hydraulics*.

As complex as some mechanical activities are, the MAVCC format presents the procedures in logically ordered objectives that facilitate a comfortable learning rate. The format also frees the instructor to concentrate on reinforcing classroom instruction with films, field trips, and other activities that serve to maintain student interest at a high level and motivate students to learn and do.

Despite careful planning and editing, we know that the text may perhaps contain a typographical error or two. Letting us know when you find such items will be a great help in improving the product before reprint time. But most of all, your input about the major elements in the book will be valuable help for changing or adding objectives when the materials are again revised and updated.

We respond to your suggestions, and we hope the quality of the materials in *Diesel Fundamentals* will serve a positive role in the classroom and provide industry with the skilled people that are so needed.

Harley Schlichting, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Greg Pierce
Executive Director
Mid-America Vocational
Curriculum Consortium

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The contents of this publication were planned and reviewed by:

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Special appreciation is extended to those who served on the original advisory committee representing the many MAVCC states, to the original author, William Foutes, and to the authors of the second revision, Bill Guynes, Marvin Kubuk, and Joe Mathis.

USE OF THIS PUBLICATION

Instructional Units

Diesel Fundamentals contains 19 units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Following is a list of the performance terms and their synonyms which may have been used in this material:

Name	Identify	Describe
Label	Select	Define
List in writing	Mark	Discuss in writing
List orally	Point out	Discuss orally
Letter	Pick out	Interpret
Record	Choose	Tell how
Repeat	Locate	Tell what
Give	Label	Explain

Order

Arrange
Sequence
List in order
Classify
Divide
Isolate
Sort

Distinguish

Discriminate

Construct

Draw
Make
Build
Design
Formulate
Reproduce
Transcribe
Reduce
Increase
Figure

Demonstrate

Show your work
Show procedure
Perform an experiment
Perform the steps
Operate
Remove
Replace
Turn off/on
(Dis) assemble
(Dis) connect

Additional Terms Used

Evaluate
Complete
Analyze
Calculate
Estimate
Plan
Observe
Compare
Determine
Perform

Prepare
Make
Read
Tell
Teach
Converse
Lead
State
Write

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives to meet the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

DIESEL FUNDAMENTALS

INSTRUCTIONAL TASK ANALYSIS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
SECTION A — ORIENTATION	
UNIT I: INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY	
	1. Terms and definitions
	2. Occupational outlook for diesel mechanics
	3. Places that employ diesel mechanics
	4. Requirements for entry into the diesel program
	5. Diesel engine applications
	6. Colors of the safety color code and their applications
	7. Personal safety rules
	8. Statements concerning personal safety
	9. Sources of accidents with the injury
	10. Four classes of fire
	11. Types of fire extinguishers and the classes of fire they are used on
12. Compile a list of employment opportunities in diesel mechanics in your community.	
13. Write a resumé.	
14. Complete an employment application form.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
15. Complete a safety pledge form.	
16. Complete an individual student shop safety inspection.	

UNIT II: BASIC SHOP TOOLS

1. Basic shop tools
2. Types of screwdrivers
3. Types of hammers
4. Types of pliers
5. Types of wrenches
6. Types of cold chisels
7. Types of punches
8. Types of file teeth
9. Types of pullers
10. Types of feeler gauges
11. Types of taps and functions
12. Types of micrometers
13. Ways to extract a screw
14. Principal parts of a twist drill
15. Shop tools used for measuring shaft speed
16. Correct and incorrect methods of using and maintaining basic shop tools
17. Precautions for correct use of the hacksaw

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
18. Read micrometer settings.	
19. Read vernier micrometer settings.	
20. Sharpen a twist drill.	
21. Drill holes with a drill press.	
22. Sharpen a cold chisel.	
23. Dress a grinding wheel.	
24. Check a torque wrench for accuracy.	
25. Tin a soldering gun.	
26. Use a file.	
27. Use the outside micrometer.	
28. Use the vernier calliper to take inside, outside, and depth measurements.	
29. Use the depth micrometer.	
30. Use a dial indicator.	
31. Use a cylinder bore gauge.	
32. Use the telescoping gauge.	

UNIT III: TEST EQUIPMENT AND SERVICE TOOLS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Differences in test equipment and service tools
	3. Types of test equipment
	4. Types of service tools
	5. Test equipment and its function
	6. Service tools and their functions

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

7. Check compression with a compression gauge.

8. Check bearing clearance with Plastigage®.

9. Test radiator with radiator tester.

10. Test a thermostat.

UNIT IV: FASTENERS

1. Terms and definitions
2. Qualities of fasteners
3. Typical fasteners
4. Typical bolt head styles
5. Bolt and thread measuring terms and their locations
6. SAE grade of metric bolts and nuts
7. Typical nuts
8. Special purpose nuts with locking or self-locking features
9. Methods used to remove a seized nut
10. Types of washers
11. Tools used to restore bolt threads
12. Tools used to restore internal threads
13. Devices for locking nuts or bolts
14. Types of machine screw head designs
15. Types of snap rings

JOB TRAINING: What the Worker Should Be Able to Do
(Psychomotor)

RELATED INFORMATION: What the Worker Should Know
(Cognitive)

16. Match wrench with the correct size bolt (standard).

17. Match wrench with the correct size bolt (standard).

18. Measure bolt and threads.

19. Match wrench with the correct size bolt (metric).

20. Match wrench with the correct size bolt (metric).

21. Draw a twist drill to correct center, and extract a broken bolt, stud, or screw.

22. Cut external threads.

23. Cut internal threads.

UNIT V: BEARINGS

1. Terms and definitions

2. Functions of bearings

3. Basic types of bearings

4. Axial and radial load forces on bearings

5. Types of bearings and the advantages and disadvantages of each type

6. Names of plain bearings

7. Materials from which bearings may be constructed

8. Factors influencing the distribution of lubricant to the bearings

9. Common methods of lubricating bearings

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	10. Causes of bearing failure in plain bearings
	11. Reasons for bearing crush
	12. Types of anti-friction bearings
	13. Conditions that determine the load carrying capacity of anti-friction bearings
	14. Ball bearing races and ball bearings
	15. Ball bearings and their design
	16. Types of roller bearings
	17. Types of needle bearings
	18. Mountings for anti-friction bearings
	19. Bearing maintenance tips
20. Remove and install camshaft bearings (friction).	
21. Remove and install an anti-friction bearing.	
22. Check Detroit diesel idler gear bearing pre-load, spring scale method.	
23. Clean and lubricate (pack) an anti-friction bearing.	

UNIT VI: SEALS

	1. Terms and definitions
	2. Uses of seals
	3. Types of seals and their uses
	4. Places where dynamic seals are used
	5. Places where static seals are used

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	6. Dynamic seals and their functions
	7. Static seals and their functional location
	8. Sealants and related terms
9. Install a radial lip type seal.	
10. Remove rear main seal and wear sleeve.	
11. Install rear main seal and wear sleeve.	

SECTION B — ENGINE PRINCIPLES AND COMPONENTS
UNIT I: ENGINE OPERATING PRINCIPLES

	1. Terms and definitions
	2. Basic parts of a diesel engine
	3. Basic diesel engine parts and their functions
	4. The sequence of operation of the diesel engine
	5. What happens during each stroke of a four-stroke cycle engine
	6. Differences between two-stroke and four-stroke cycle engines
	7. The characteristics of two-stroke cycle and four-stroke cycle engines
	8. Differences between diesel engines and gasoline engines
9. Locate intake and exhaust valves on an engine.	
10. Locate TDC #1 cylinder on compression stroke of an engine.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT II: CYLINDER HEAD ASSEMBLY

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Major parts in a cylinder head assembly
	3. Forms of cylinder head castings that may be found on a diesel engine
	4. Primary parts of a valve assembly
	5. Types of valve rotators
	6. Types of valve arrangement
	7. Locations of turbulence chambers in an engine
	8. Forms of engine valves
	9. Factors determining cylinder head size
10. Remove, inspect, and install a cylinder head.	
11. Disassemble and service a valve train.	
12. Service valve guides.	
13. Grind valve seats.	
14. Replace valve seat inserts.	
15. Assemble a cylinder head.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

RELATED INFORMATION: What the Worker Should Know (Cognitive)

UNIT III: PISTON AND CONNECTING ROD ASSEMBLIES

1. Terms and definitions
2. Primary parts of a piston and connecting rod assembly
3. Functions of the piston
4. Parts of a piston
5. Functions of piston rings
6. Types of piston rings
7. Common types of ring end gaps
8. Possible causes of high oil consumption and blow-by
9. Types of piston pins
10. Types of construction for the cap end of a connecting rod
11. Reasons for markings on the connecting rod, piston, and bearing cap
12. Remove piston and connecting rod assembly.
13. Remove piston rings and piston from rod.
14. Clean pistons.
15. Inspect and measure pistons for wear.
16. Inspect connecting rod.

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
17. Assemble piston to rod and install rings.	
18. Install piston and connecting rod assembly into cylinder.	

UNIT IV: CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Parts on some diesel engines that are actuated by the camshaft
	3. Parts of a camshaft
	4. Parts in a valve train
	5. Valve timing on a four-cycle engine
	6. Valve timing on a two-cycle engine
	7. Gears found in a typical gear train
	8. Gears which are marked in the gear train to insure correct valve timing
	9. Methods of driving the camshaft
10. Remove a camshaft.	
11. Remove camshaft gear.	
12. Inspect camshaft and bearings.	
13. Inspect camshaft lobe lift.	
14. Install a camshaft gear, and install camshaft into engine.	
15. Adjust valve clearance on a valve-in-head six-cylinder four-cycle engine.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
16. Remove camshaft from a Detroit diesel engine.	
17. Inspect camshaft on a Detroit diesel engine.	
18. Install camshaft in a Detroit diesel engine.	

UNIT V: CYLINDER BLOCKS AND LINERS

	1. Terms and definitions
	2. Types of cylinder block construction
	3. Advantages a removable liner has over an integral cylinder bore
	4. Types of wet and dry liners
5. Remove a cylinder liner.	
6. Clean and inspect a cylinder liner.	
7. Clean and inspect a cylinder block.	
8. Install cylinder liner into cylinder block and check liner protrusion.	

UNIT VI: CRANKSHAFTS AND BEARINGS

	1. Terms and definitions
	2. Parts of a crankshaft
	3. Arrangement of crankcase throws and the number of cylinders in the engine
	4. Steps in determining corresponding cylinders of a four-cycle engine

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Ways crankshaft balance is maintained
	6. Lubrication of the crankshaft and surrounding parts
	7. Difference between a bushing and a bearing
	8. Materials used in making bearing linings
	9. Types of bearing locks
	10. Definition of bearing crush
	11. Purpose of oil grooves in the bearing
	12. Types of thrust bearings
	13. Engine indications of bearing failure
	14. Percentages of bearing failure and the causes of bearing failure
	15. Functions of the flywheel
	16. Types of vibration dampers
17. Determine piston location, stroke position, and valve adjustment of a four-cycle four cylinder engine.	
18. Determine piston location, stroke position, and valve adjustment of a four-cycle six cylinder engine.	
19. Determine piston location, stroke piston, and valve adjustment of a four-cycle eight cylinder engine.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
20. Remove a crankshaft.	
21. Inspect and measure a crankshaft and bearings.	
22. Install bearings and crankshaft.	

SECTION C — AUXILIARY SYSTEMS
UNIT I: LUBRICANTS AND LUBRICATION SYSTEMS

1. Terms and definitions
2. Characteristics of a good engine oil
3. SAE; viscosity number
4. API classification system
5. Facts about engine oil
6. Rules for selection and use of engine oil
7. Facts about oil contamination
8. Diagnostic tests related to oil analysis
9. Types of oil filters
10. Functions of the lubrication system
11. Components of the lubrication system
12. Components related to lubrication systems and their purposes
13. Lubricating valves and their purposes
14. Types of oil pumps

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	15. Differences between internally and externally mounted oil coolers
	16. Facts about mechanical and electrical oil pressure indicating systems
	17. Facts about oil temperature indicating systems
	18. Components of an oil pressure shutdown or alarm circuit
	19. Steps of operation of the oil pressure shutdown or alarm circuit
20. Check oil pressure on a live engine.	
21. Change an oil filter.	

UNIT II: COOLANTS AND COOLING SYSTEMS

	1. Terms and definitions
	2. Types of cooling systems used on modern engines
	3. Parts of a cooling system and their functions
	4. Parts of an air cooled engine and their functions
	5. Requirements of a good antifreeze
	6. Preventive maintenance procedures for maintaining a cooling system
	7. Functions of the cooling system
	8. Effects of an engine running too hot

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	9. Effects of an engine running too cold
	10. Parts in a liquid cooling system
	11. Types of radiators
	12. Functions of the radiator cap
	13. Types of fans used in cooling systems
	14. Types of fan controls
	15. Types of temperature gauges
	16. Purposes for using a coolant filter or conditioner in the cooling system
	17. Functions of the thermostat
	18. Types of thermostats
	19. Common materials that may restrict radiator coolant flow
	20. Primary parts of a water pump
21. Test for combustion leakage into the cooling system.	
22. Test for air in cooling system.	
23. Clean the cooling system.	

UNIT III: AIR INTAKE AND EXHAUST SYSTEMS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Parts of an air intake system
	3. Parts of an exhaust system
	4. Types of air cleaners and their processes

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Difference between scavenging for a two-stroke cycle engine and a four-stroke cycle engine
	6. Types of air induction systems
	7. Difference between positive displacement and centrifugal superchargers
	8. Advantages of a turbocharged engine
9. Test an engine for air flow restriction.	
10. Remove and install a turbocharger.	
11. Test a turbocharger.	
12. Inspect, remove, and install a roots-type blower.	

UNIT IV: ENGINE BRAKES AND RETARDERS

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	1. Terms and definitions
	2. Operation of Jacobs engine brake
	3. Troubleshooting procedures for the Jacobs engine brake
	4. Advantages of the Jacobs engine brake
	5. Operation of the BrakeSaver
6. Adjust a Jacobs engine brake on a Detroit diesel.	
7. Troubleshoot a Caterpillar BrakeSaver.	
8. Remove a BrakeSaver on a Caterpillar diesel engine.	
9. Disassemble a BrakeSaver.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
10. Assemble a BrakeSaver.	
11. Install a BrakeSaver.	
12. Install a Jacobs engine brake on a Mack diesel.	
13. Adjust slave piston of a Jacobs engine brake on a Mack diesel.	

SECTION D — MAINTENANCE

UNIT I: PREVENTIVE MAINTENANCE

	1. Terms and definitions
	2. Facts about daily PM's
	3. Facts about weekly PM's
	4. Facts about hourly, mileage, or "as required" PM's
5. Perform a daily PM service.	
6. Perform a weekly PM service.	
7. Perform a mileage, hourly, or "as required" PM service.	

UNIT II: TROUBLESHOOTING AND TESTING OF ENGINES

	1. Terms and definitions
	2. Steps in troubleshooting and testing an engine
	3. Major checkpoints when inspecting a diesel engine
	4. Major check to make when operating an engine

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
	5. Tests made with a dynamometer
	6. Factors necessary for an engine to produce horsepower
	7. Possible causes of a diesel engine being hard to start or not starting
	8. Possible causes of a diesel engine starting but not running
	9. Items which would cause a diesel engine to misfire
	10. Items which would cause a diesel engine to knock
	11. Items which would cause a diesel engine to overheat
	12. Items which would cause a diesel engine to have lack of power
	13. Items which would cause a diesel engine to use too much oil
	14. Causes of high oil pressure
	15. Causes of low oil pressure
16. Complete a diesel troubleshooting guide.	
17. Load test an engine with a dynamometer.	
18. Test engine cylinder compression.	
19. Check air intake system for restrictions.	
20. Check crankcase pressure, exhaust back pressure, and air box pressure.	

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)	RELATED INFORMATION: What the Worker Should Know (Cognitive)
UNIT III: TUNE-UP AND ADJUSTMENT	
	1. Terms and definitions
	2. Major items to include in a visual inspection checklist
3. Tune-up and service a diesel engine.	
4. Tune-up a Cummins diesel engine (Torque Method).	
5. Tune-up a Cummins diesel engine (Dial Indicator Method).	
6. Tune-up a Detroit diesel engine.	
7. Tune-up a 3400 series Caterpillar diesel engine.	

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to compile a list of employment opportunities in diesel mechanics in the community, write a resume, and complete an application form. The student should also be able to complete a safety pledge form, and complete an individual shop safety inspection. Competencies will be demonstrated by completing the assignment sheets and unit test with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to diesel mechanics and shop safety with the correct definitions.
2. Complete statements concerning the occupational outlook for diesel mechanics.
3. Select places that employ diesel mechanics.
4. Complete requirements for entry into the diesel program.
5. List diesel engine applications.
6. Match the colors of the safety color code with the correct applications.
7. Complete a list of personal safety rules.
8. Select true statements concerning personal safety.
9. Match possible sources of accidents with the injury which may occur.

OBJECTIVE SHEET

10. Match the four classes of fire with the correct statements defining each class.

11. Match the type or types of fire extinguishers with the class of fire they are used on.

12. Compile a list of employment opportunities in diesel mechanics in your community. (Assignment Sheet #1)

13. Write a resume. (Assignment Sheet #2)

14. Complete an employment application form. (Assignment Sheet #3)

15. Complete a safety pledge form. (Assignment Sheet #4)

16. Complete an individual student shop safety inspection. (Assignment Sheet #5)

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate the use of fire extinguishers.
2. Take students on tour of shop prior to completion of Assignment Sheet #5.
3. Have speaker from the local fire department demonstrate the correct use of fire extinguishers.
4. Show films dealing with diesel mechanics and shop safety. Possible films are listed on the following page as Suggested Supplemental Resources.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *The ABC's of Fire Protection.* Belleville, NJ: Walter Kidde and Company.

B. *An Accident Prevention Program for School Shops and Laboratories.* Office of Education/U.S. Department of Health, Education, and Welfare.

REFERENCES USED IN DEVELOPING THIS UNIT

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

D. *Making Safety Work.* Chicago, IL: National Safety Council, 1976.

E. *Safety Practices and Procedures in School Shops.* New Jersey: Division of Vocational Education/Department of Education.

F. Schulz, Eric. *Diesel Mechanic.* 2nd ed. Gregg Division/McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Safety films

1. *Safety In The Shop: Basic Practices*
Coronet Films
65 E. South Water Street
Chicago, IL 60601
1 800 621-2131

2. *Shake Hands With Danger*
Calvin Productions
1105 Truman Road
Kansas City, MO 64106
(816) 471-7800

B. Films for the diesel engine

1. *ABC's of the Diesel Engine*
General Motors Corp.
3044 W. Grand Boulevard
Detroit, MI 48238

2. *Introduction to Diesel Engines*
Caterpillar Tractor Company
Building JJ Service Training
600 W. Washington Street
East Peoria, IL 61630

(NOTE: Call the local distributor in your area for more information on available films on proper shop procedures.)

C. Safety signs and posters

National Safety Council
444 North Michigan Avenue
Chicago, IL 60611
1 800 621-7619 (toll free outside Illinois)

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

INFORMATION SHEET

I. **Terms and definitions**

A. Accident — Any suddenly occurring, unintentional event which causes injury or property damage

B. Adjustments — To regulate clearances and pressures within tolerance to manufacturer's specifications

C. Disassemble — To take apart in a clean, correct orderly manner

D. First aid — Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

E. Hazardous waste — Leftover by-products that contain dangerous chemicals that could be harmful to the environment or to living things coming in contact with them

F. Liability — Legal responsibility which binds an individual in law and justice to do something which may be enforced by action

G. Measure — To determine the size of an object and compare with a standard size to determine if the object shows signs of wear

H. Reassemble — To put back together new or rebuilt parts in a clean, correct orderly manner

I. Repair — To put back in good condition after damage

J. Safety — State or condition of being free from danger, risk, or injury

K. Test — To operate equipment or engine to check performance and adjustment

L. Troubleshooting — The act of analyzing, testing, and measuring the engine to remedy the cause of trouble

II. **Occupational outlook**

A. Job opportunities result each year from the need to replace experienced mechanics who are promoted, retired, or transferred to related fields of work.

B. Number of diesel engine applications increases each year requiring more mechanics to service them.

C. Demand for diesel power has increased due to the added economy, endurance, and high efficiency of the diesel engine as compared to other power units.

INFORMATION SHEET

III. **Places of employment for diesel mechanics**

A. Independent repair shops

B. Service departments of dealers and distributors

C. Sales agencies and manufacturers of diesel engines

D. Truck leasing companies

E. Federal, state, and local government vehicle maintenance depots

F. Electric power plants

G. Railroad locomotive shops

H. Fuel injection repair station

(NOTE: This has limited or low employment.)

I. Marine

J. Oil fields

K. Mining

L. Agriculture

M. Heavy equipment

N. Bus garage

O. Electrical repair shop

P. Remanufacture shop

IV. **Student requirements for the diesel mechanics program**

A. Operate the shop equipment correctly.

B. Be safety conscious; follow safety regulations.

C. Take instructions readily; follow directions.

D. Be a good citizen.

E. Control temper.

F. Have enthusiasm about work.

INFORMATION SHEET

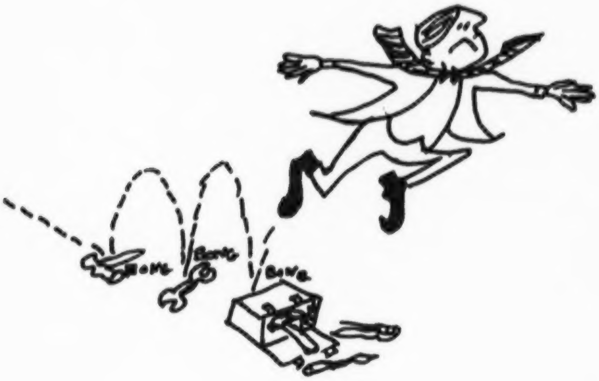
G. Have pride in the trade and workmanship.

H. Be conscious of waste in materials and man-hours.

I. Be punctual.

J. Practice good housekeeping. (Transparency 1 and Figure 1)

FIGURE 1



V. Diesel engine applications

A. Electric power plants

B. Automotive vehicles (trucks, buses, and automobiles)

C. Farm tractors and equipment

D. Rail locomotives

E. Construction equipment (such as rock crushers, cranes, and loaders)

F. Road building equipment

G. Marine engines

INFORMATION SHEET

VI. **Colors and applications of the safety color code**

A. Green — Designates safety and the location of first aid equipment

B. Yellow — Designates caution and marks physical hazards

C. Orange — Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure

D. Red — Identifies the location of fire fighting equipment and apparatus

(NOTE: Emergency fire exits shall be designated in red. Buttons or levers for electrical switches used for the stopping of machinery should be designated in red. Gasoline cans should be painted red with additional identification in the form of a yellow band around the can.)

E. Blue — Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment

(NOTE: A blue tag should be lettered "Out of Order.")

F. Black, white, or combinations of black and white — Designates traffic and housekeeping markings

G. Purple — Designates radioactive material

VII. **Personal safety rules**

A. Wear shop clothing and work shoes appropriate to the activity being performed.

B. Confine long hair at all times.

C. Always wear eye protection when in the shop area, and as required by school policy.

D. Confine loose clothing such as ties or scarves when working around machine tools or rotating equipment.

E. Remove all jewelry such as rings, earrings, and necklaces when working in the shop.

F. Conduct yourself in a manner conducive to safe shop practices.

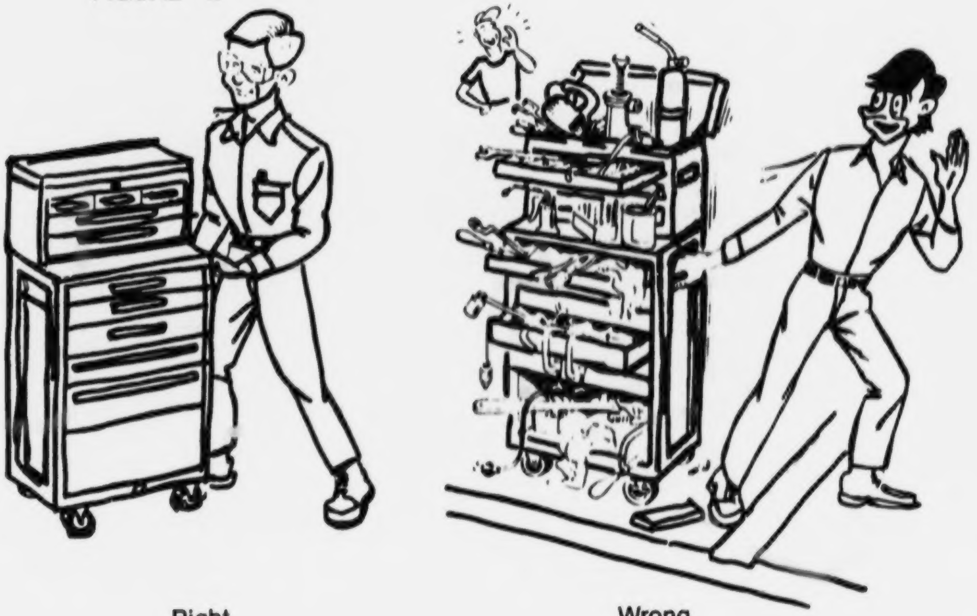
G. Keep mentally alert to shop hazards.

INFORMATION SHEET

VIII. General shop safety rules

A. Keep all hand tools clean and the work area in safe working order. (Figure 2)

FIGURE 2

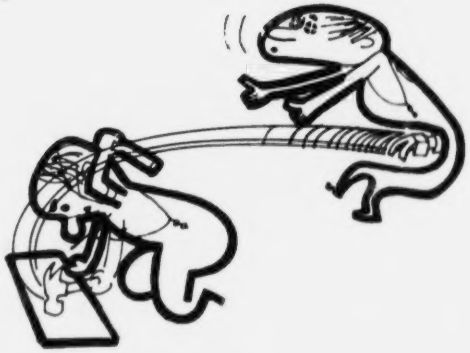


Right

Wrong

B. Report defective tools, machines, and equipment to the instructor. (Figure 3)

FIGURE 3



C. Retain all guards and safety devices except with the specific authorization of the instructor.

INFORMATION SHEET

D. Operate powered equipment only after receiving instruction on how to operate the machine safely.

E. Report all accidents to the instructor regardless of nature or severity.

F. Turn off the power before leaving a machine tool.

G. Make sure all guards and barriers are in place and adjusted properly before starting a machine tool.

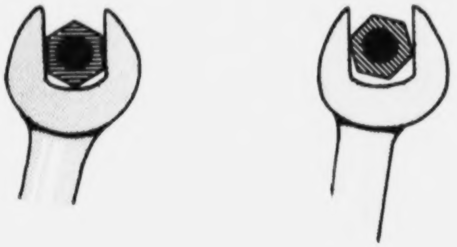
H. Disconnect the power from machine tools before performing any maintenance task.

I. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it.

J. Use correct type and proper size of wrenches for nuts, bolts, and objects to be turned or held. (Figure 4)

(NOTE: The type refers to metric or standard.)

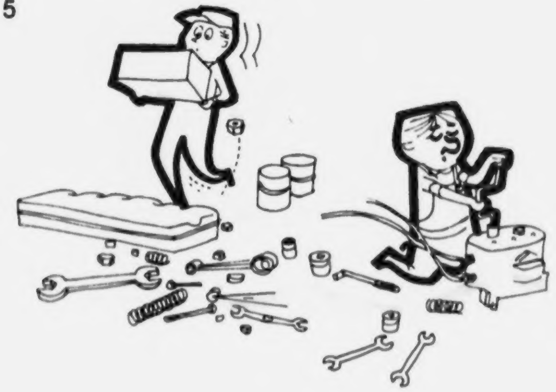
FIGURE 4



Correct size Too large

K. Keep the shop or laboratory floor clear of tools, scraps, and litter. (Figure 5)

FIGURE 5



INFORMATION SHEET

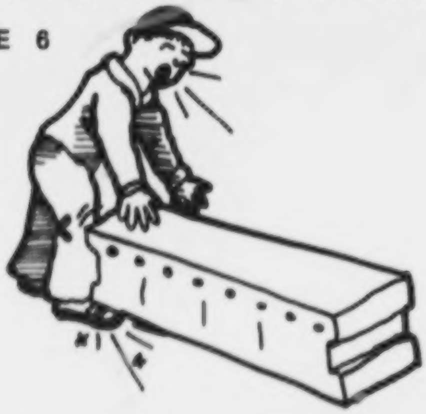
L. Clean up any spilled liquids immediately.

M. Store oily rags or oily waste in metal containers.

N. Clean the chips from a machine with a brush. Do not use a rag or bare hands.

O. Use proper support for all heavy objects. (Figure 6)

FIGURE 6



P. Practice tool motto: "Get, use, and put away."

IX. **Sources of accidents and injuries which may occur**

A. Horseplay — May cause others to fall against sharp objects or moving machinery.

B. Air hose — One blast may rip clothing or skin.

C. Grinder — May cause eye or face injury from flying sparks or metal chips

D. Batteries — May explode when near open flame or electrical spark

E. Moving parts — May catch fingers or clothing

F. Loose clothing — May catch in rotating parts

G. Tools — Sharp edges may puncture skin

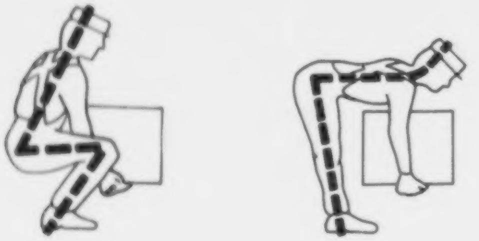
H. Electrical power tools — May cause shock if not grounded

I. Lack of or improper supporting device under heavy objects — A fall may cause a fatal injury.

INFORMATION SHEET

J. Lifting heavy objects — May cause severe back injury (Figure 7)

FIGURE 7



Lift this way Not this way

K. Welding — Can cause injury to eyes and to skin if protective equipment is not worn

L. Pneumatic tools — High air pressure may seriously damage eyes and skin.

X. **Classes of fire**

A. Class A — Fires that occur in ordinary combustible materials

Examples: Wood, rags, and rubbish

B. Class B — Fires that occur with flammable liquids

Examples: Gasoline, oil, grease, paints, and thinners

C. Class C — Fires that occur in or near electrical equipment

Examples: Motors, switchboards, and electrical wiring

D. Class D — Fires that occur in combustible metals

Examples: Magnesium, titanium, zirconium, lithium, and sodium potassium

XI. **Types of fire extinguishers** (Transparency 2)

(NOTE: Other types of fire extinguishers are available for specific applications. The ones listed here are the most common types.)

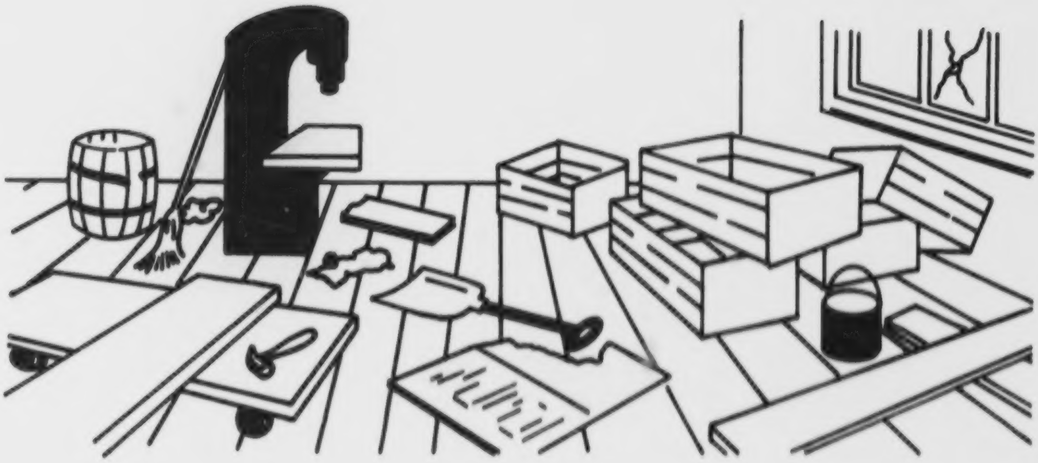
A. Pressurized water — Used on Class A fires

B. Carbon dioxide — Used on Class B and C fires

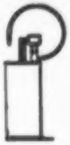
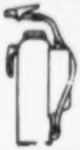
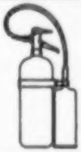
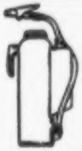
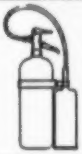
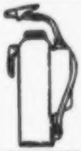
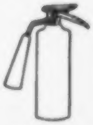
C. Multi-purpose dry chemical — Used on Class A, B, and C fires

Poor Housekeeping Indicators

1. Objects and Materials on Floors
2. Equipment Out of Place
3. Poor Storage Practice
4. Poor Waste Disposal System
5. Dirty Walls, Windows, and Lights
6. Fire Hazards



Types of Fire Extinguishers

Type of Fire	Approved Type of Extinguisher			
	Pressurized Water	Carbon Dioxide	Multi-Purpose Dry Chemical	Dry Powder
Class A Fires ORDINARY COMBUSTIBLES • Wood • Paper • Cloth, etc.				
Class B Fires FLAMMABLE LIQUIDS, GREASE • Gasoline • Paints • Oils, etc.				
Class C Fires ELECTRICAL EQUIPMENT • Motors • Switches, etc.				
Class D Fires COMBUSTIBLE METALS • Iron • Magnesium				

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

ASSIGNMENT SHEET #1 — COMPILE A LIST OF EMPLOYMENT OPPORTUNITIES IN DIESEL MECHANICS IN YOUR COMMUNITY

NAME ______________________________ SCORE ____________

Directions: Make a list of diesel mechanic shops in your community, and state the services that are offered.

MECHANICS SHOP	SERVICES
1. ______________________	______________________
______________________	______________________
	______________________
2. ______________________	______________________
______________________	______________________
	______________________
3. ______________________	______________________
______________________	______________________
	______________________
4. ______________________	______________________
______________________	______________________
	______________________
5. ______________________	______________________
______________________	______________________
	______________________
6. ______________________	______________________
______________________	______________________
	______________________

ASSIGNMENT SHEET #1

	MECHANICS SHOP	SERVICES
7.	____________________	____________________
	____________________	____________________
		____________________
8.	____________________	____________________
	____________________	____________________
		____________________
9.	____________________	____________________
	____________________	____________________
		____________________
10.	____________________	____________________
	____________________	____________________
		____________________

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

ASSIGNMENT SHEET #2 — WRITE A RESUMÉ

NAME ____ SCORE ____________

Directions: Write a resume using accurate facts about yourself. Use the information below and the sample resume included in this assignment sheet as guides. A good resumé should immediately give prospective employers a brief summary of your accomplishments, educational background, work experience (paid, unpaid employment), skills, and job objective. It is not necessary to use the exact wording and outline form used on the sample resumé, but it is necessary that your resume be neat and balanced and contain all the information which might help you get a job. Keep a current copy of the resumé and use it to apply for jobs.

1. Inspect several resume formats and choose one that best fits your needs, or use the example included in this assignment sheet as a guide.
2. Type your resume on $8^1/_2$" × 11" white paper; try to limit the number of pages.
3. Keep the resume error free.

   (NOTE: Many employers will not consider persons who have resumes that include misspelled words and typographical errors.)
4. Use an outline form.
5. Put your name prominently at the top in the upper left-hand corner; beneath your name, give full street address, city, state, zip code, telephone number with area code, and a number where messages can be accepted.

   (NOTE: Do not print a photo on the resumé. If a photo is requested, attach it to the resumé.)
6. Under Personal Data include your birthdate, height, weight, health, and marital status; do not include religious and political affiliations.

   (NOTE: The above information is optional.)
7. Describe your job objective or career goal briefly.
8. Describe your educational background, giving names of schools, dates of enrollment, and diploma or degrees received.
9. List related subjects studied; include grade averages, if favorable.
10. List student activities and awards.

ASSIGNMENT SHEET #2

11. List hobbies and extracurricular activities if they are relevant.

12. List your past employment, starting with your most recent job; include name of firm, mailing address, job title, starting and ending dates of employment, name of immediate supervisor, and phone number.

    (NOTE: Always maintain chronological order on events.)

13. List duties of your last job.

    (NOTE: Concentrate on skills you have used; let the employer know what you can do. Remember, you have to prove your value to the business, especially if you have little experience.)

14. List three people as character references; include their complete mailing addresses and phone numbers.

    (NOTE: Ask permission before you use anyone as a reference.)

15. List one or more work references; include people that you have actually worked for.

    (NOTE: Avoid listing relatives as a reference unless you have actually worked for them on a salary basis.)

16. Write "Confidential" at the top of the resume if you don't want your current employer to know you are looking for other employment.

17. Proofread your resume carefully and retype if necessary; reproduce several copies on white bond paper.

    (NOTE: Your resume's physical appearance is VERY IMPORTANT. Avoid using ditto or carbon copies. Be sure to proofread the printer's work. Always bring extra copies to the interview. Leave one copy of the resumé with the interviewer and use one as a reference when filling out the application form. You should also mail one resumé with your letter of application.)

ASSIGNMENT SHEET #2

SAMPLE RESUMÉ

TERRY McKRACKEN

ADDRESS:

Present:	774 E. Adams Street YourTown, YourState 77704 (405) 555-7779	Permanent:	Route #3 AnyTown, YourState 77704 (405) 555-4433

PERSONAL DATA:

Age: 17
Birthdate: Jan. 21, 1970
Height: 5′7″
Weight: 160 lbs.

Health: Excellent
Marital Status: Single

JOB OBJECTIVE:

Assistant Manager

ULTIMATE GOAL:

Truck Garage Manager

EDUCATION:

AnyTown High School, AnyTown, YourState 1983-87
Grade Average: 3.5 on a 4.0 scale

RELATED SUBJECTS STUDIED:

High School

Diesel Mechanics — 4 semesters
Typing — 1 semester
Bookkeeping — 1 semester
Ag 2 — 2 semesters

STUDENT ACTIVITIES:

President, Senior Class
President, Diesel Mechanics Group
Treasurer, Baptist Youth Fellowship Organization
Reporter, VICA

ASSIGNMENT SHEET #2

WORK EXPERIENCE:

Name: Ken's Truck Garage
612 W. Oak
YourTown, YourState 77704
(405) 555-7212

Job Title: Mechanics Helper
Dates: June 1, 1985 to Present

Supervisor: Mr. Ken Bates

Duties: Helping other mechanic
Keeping shop clean
Cleaning parts

Name: John Farmer
R.R. #2
YourTown, YourState 77704
(405) 555-2000

Job Title: Farm Worker
Dates: Jan. 1, 1981 to May 15, 1985

Supervisor: Mr. John Farmer

Duties: Feeding livestock
Machinery operation
Hay hauling

CHARACTER REFERENCES:

1. Mr. Sammy Davis (918) 555-2442
   Vocational Agriculture Instructor
   AnyTown High School
   AnyTown, YourState 77703

2. Mr. John Hammer (918) 555-3333
   Friend and Neighbor
   772 E. Adams Street
   YourTown, YourState 77703

3. Mrs. Jerri Smith (918) 555-1000
   Youth Director, Parkview Baptist Church
   711 Fellowship Circle
   AnyTown, YourState 77702

WORK REFERENCE: (with permission)

Mr. Ken Bates (405) 555-7212
Owner/Manager
Ken's Truck Garage
612 W. Oak
YourTown, YourState 77704

ASSIGNMENT SHEET #2

RESUMÉ

NAME:

ADDRESS:

Present: Permanent:

PERSONAL DATA:

Age: Health:
Birthdate: Marital Status:
Height:
Weight:

JOB OBJECTIVE:

ULTIMATE GOAL:

EDUCATION:

RELATED SUBJECTS STUDIED:

STUDENT ACTIVITIES:

ASSIGNMENT SHEET #2

WORK EXPERIENCE:

Name:	Name:
Job Title:	Job Title:
Dates:	Dates:
Supervisor:	Supervisor:
Duties:	Duties:

CHARACTER REFERENCES:

1.

2.

3.

WORK REFERENCES: (with permission)

D-25-A

ASSIGNMENT SHEET #3

"WE ARE AN EQUAL OPPORTUNITY EMPLOYMENT COMPANY. WE ARE DEDICATED TO A POLICY OF NON-DISCRIMINATION IN EMPLOYMENT ON ANY BASIS INCLUDING RACE, CREED, COLOR, AGE, SEX, RELIGION OR NATIONAL ORIGIN OR PHYSICAL DEFECTS."

APPLICATION FOR EMPLOYMENT

PERSONAL INFORMATION

DATE ______

NAME ______
LAST FIRST MIDDLE

PRESENT ADDRESS ______
STREET CITY STATE ZIP

PERMANENT ADDRESS ______
STREET CITY STATE ZIP

PHONE NO. ______ SOCIAL SECURITY NUMBER ______

______ REFERRED BY ______

EMPLOYMENT DESIRED

POSITION ______ DATE YOU CAN START ______ SALARY DESIRED ______

ARE YOU EMPLOYED NOW? ______ IF SO MAY WE INQUIRE OF YOUR PRESENT EMPLOYER? ______

HAVE YOU EVER APPLIED TO THIS COMPANY BEFORE? ______ WHERE ______ WHEN ______

EDUCATION	NAME AND LOCATION OF SCHOOL	YEARS ATTENDED	DATE GRADUATED	SUBJECTS STUDIED
GRAMMAR SCHOOL				
HIGH SCHOOL				
COLLEGE				
TRADE, BUSINESS, OR CORRESPONDENCE SCHOOL				

SUBJECTS OF SPECIAL STUDY OR RESEARCH WORK ______

U.S. MILITARY OR NAVAL SERVICE ______ RANK ______ PRESENT MEMBERSHIP IN NATIONAL GUARD OR RESERVES ______

ACTIVITIES OTHER THAN RELIGIOUS (CIVIC, ATHLETIC, FRATERNAL, ETC.) ______

Exclude organizations, the name or character of which indicates the race, creed, color, or national origin of its members.

(CONTINUED ON OTHER SIDE)

ASSIGNMENT SHEET #3

FORMER EMPLOYERS (LIST BELOW LAST FOUR EMPLOYERS, STARTING WITH LAST ONE FIRST)

DATE MONTH & YEAR	NAME AND ADDRESS OF EMPLOYER	SALARY	POSITION	REASON FOR LEAVING
FROM				
TO				
FROM				
TO				
FROM				
TO				
FROM				
TO				

REFERENCES: Give below the names of two persons not related to you, whom you have known at least one year.

	NAME	ADDRESS	BUSINESS	YEARS ACQUAINTED
1.				
2.				

PHYSICAL RECORD:

List any physical defects

WERE YOU EVER INJURED? GIVE DETAILS

HAVE YOUR ANY DEFECTS IN HEARING? IN VISION? IN SPEECH?

IN CASE OF EMERGENCY NOTIFY

NAME ADDRESS PHONE NO.

I AUTHORIZE INVESTIGATION OF ALL STATEMENTS CONTAINED IN THIS APPLICATION. I UNDERSTAND THAT MISREPRESENTATION OR OMISSION OF FACTS CALLED FOR IS CAUSE FOR DISMISSAL. FURTHER, I UNDERSTAND AND AGREE THAT MY EMPLOYMENT IS FOR NO DEFINITE PERIOD AND MAY, REGARDLESS OF THE DATE OF PAYMENT OF MY WAGES AND SALARY, BE TERMINATED AT ANY TIME WITHOUT ANY PREVIOUS NOTICE.

DATE SIGNATURE

DO NOT WRITE BELOW THIS LINE

TO BE COMPLETED DAY EMPLOYMENT BEGINS

DATE________________

HEIGHT WEIGHT AGE DATE OF BIRTH

SINGLE MARRIED WIDOWED CITIZEN U.S.A. SEX

THE ABOVE INFORMATION NEEDED FOR PENSION, HOSPITALIZATION, INSURANCE, ETC., AND NOT FOR HIRING PURPOSES

INTERVIEWED BY DATE REMARKS

NEATNESS CHARACTER

PERSONALITY ABILITY

HIRED FOR DEPT. POSITION WILL REPORT SALARY WAGES

APPROVED: 1. 2. 3.

EMPLOYMENT MANAGER DEPT. HEAD GENERAL MANAGER

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

ASSIGNMENT SHEET #4 — COMPLETE A SAFETY PLEDGE FORM

NAME ______________________________ SCORE ____________

Directions: Read and complete the student safety pledge form by filling in the blanks. Return form to instructor no later than ____________________.

STUDENT SAFETY PLEDGE FORM

____________ ____________ ____________, who is enrolled in Vocational ____________ ____________, will as a part of the shop experience, operate machines, providing that the parent or guardian gives written permission.

It is understood that each student will be given proper instruction, both in the use of the equipment and in correct safety procedures concerning it, before being allowed to operate the machines. The student must assume responsibility for following safe practices; therefore, we ask that the student subscribe to the following safety pledge.

1. I PROMISE TO FOLLOW ALL SAFETY RULES FOR THE SHOP.
2. I PROMISE NEVER TO USE A MACHINE WITHOUT FIRST HAVING PERMISSION FROM THE INSTRUCTOR.
3. I WILL NOT ASK PERMISSION TO USE A PARTICULAR MACHINE UNLESS I HAVE BEEN INSTRUCTED IN ITS USE, AND HAVE MADE 100% ON THE SAFETY TEST FOR THAT MACHINE.
4. I WILL REPORT ANY ACCIDENT OR INJURY TO THE INSTRUCTOR IMMEDIATELY.

DATE ____________ STUDENT'S SIGNATURE ________________________

I hereby give my consent to allow my son or daughter to operate all the machines and equipment necessary in carrying out the requirements of the course in which he/she is enrolled.

DATE ____________ PARENT'S SIGNATURE ________________________
(If required)

Parents are cordially invited to visit the shop to inspect the machines and to see them in operation.

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

ASSIGNMENT SHEET #5 — COMPLETE AN INDIVIDUAL STUDENT SHOP SAFETY INSPECTION

NAME ____ SCORE ____________

Directions: Complete the safety inspection checklist by physically conducting an inspection of the shop area.

CHECKING PROCEDURE

Draw a circle around the appropriate letter, using the following letter scheme:

S — Satisfactory (needs no attention)
A — Acceptable (needs some attention)
U — Unsatisfactory (needs immediate attention)

Recommendations should be made in all cases where a "U" is circled. Space is provided at the end of the form for such comments.

A. GENERAL PHYSICAL CONDITION

1. Machines, benches, and other equipment are arranged to conform to good safety practices. S A U
2. Condition of stairways and ramps S A U
3. Condition of aisles S A U
4. Condition of floors S A U
5. Condition of walls, windows, and ceiling S A U
6. Illumination is safe, sufficient, and well placed. S A U
7. Ventilation is adequate and proper for conditions. S A U
8. Temperature control S A U
9. Fire extinguishers are of proper type, adequately supplied, properly located, and maintained. S A U
10. Teacher and pupils know location of and how to use proper type for various fires. S A U
11. Number and location of exits is adequate and properly identified. S A U

ASSIGNMENT SHEET #5

12. Walls are clear of objects that might fall. S A U
13. Utility lines are properly identified. S A U
14. Air in shop is free from excessive dust and smoke. S A U
15. Evaluation for the total rating of GENERAL PHYSICAL CONDITION S A U

B. HOUSEKEEPING

1. General appearance as to orderliness S A U
2. Adequate and proper storage space for tools and materials S A U
3. Benches are kept orderly. S A U
4. Corners are clean and clear. S A U
5. Special tool racks, in orderly condition, are provided at benches and machines. S A U
6. Tool, supply, and/or material room is orderly. S A U
7. Sufficient scrap boxes are provided. S A U
8. Scrap stock is put in scrap boxes promptly. S A U
9. Materials are stored in an orderly and safe condition. S A U
10. A spring lid metal container is provided for waste and oily rags. S A U
11. Dangerous materials have been stored in metal cabinets. S A U
12. Machines have been color coded. S A U
13. Safety cans are provided for flammable liquids. S A U
14. Floors are free of oil, water, and foreign material. S A U
15. Evaluation for the total rating for HOUSEKEEPING S A U

ASSIGNMENT SHEET #5

C. EQUIPMENT

1. Machines are arranged so that workers are protected from hazards of other machines and passing students. S A U
2. Danger zones are properly indicated and guarded. S A U
3. All gears and moving belts are protected by permanent enclosure guards. S A U
4. All equipment control switches are easily available to operator. S A U
5. Nonskid areas are provided around machines. S A U
6. Tools are kept sharp, clean, and in safe working order. S A U
7. Evaluation for the total rating for EQUIPMENT S A U

D. ELECTRICAL INSTALLATION

1. All switches are enclosed. S A U
2. There is a master control switch for all of the electrical installations. S A U
3. All electrical extension cords are in safe condition and are not carrying excessive loads. S A U
4. All machine switches are within easy reach of the operators. S A U
5. Individual cut-off switches are provided for each machine. S A U
6. No temporary wiring is in evidence. S A U
7. Evaluation for the total rating for ELECTRICAL INSTALLATION S A U

E. PERSONAL PROTECTION (Read only)

1. Safety glasses, goggles, or protective shields are provided and required for all work where eye hazards exist.
2. Shields and goggles are provided for welding.

ASSIGNMENT SHEET #5

3. Rings and other jewelry are removed by pupils when working in the shop.
4. Proper kind of wearing apparel is worn and worn properly for the job being done.
5. Leggings and safety shoes are worn in special classes.
6. Students are tested for safety knowledge ability.
7. Sleeves are rolled above elbows when operating machines.
8. Loose clothing of students such as ties, scarves, and loose sleeves are secured.

RECOMMENDATIONS

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms on the right with the correct definitions.

_____a. To take apart in a clean correct orderly manner

_____b. Leftover by-products that contain dangerous chemicals that could be harmful to the environment or to living things coming in contact with them

_____c. To determine the size of an object and compare with a standard size to determine if the object shows signs of wear

_____d. To put back in good condition after damage

_____e. To put back together new or rebuilt parts in a clean correct orderly manner

_____f. To regulate clearances and pressures within tolerance to manufacturer's specification

_____g. To operate equipment or engine to check performance and adjustments

_____h. The act of analyzing, testing, and measuring the engine to remedy the cause of trouble

_____i. State or condition of being free from danger, risk, or injury

_____j. Any suddenly occurring, unintentional event which causes injury or property damage

_____k. Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

_____l. Legal responsibility which binds an individual in law and justice to do something which may be enforced by action

1. Accident
2. Adjustment
3. Disassemble
4. First aid
5. Hazardous waste
6. Liability
7. Measure
8. Reassemble
9. Repair
10. Safety
11. Test
12. Troubleshooting

TEST

2. Complete statements concerning the occupational outlook for diesel mechanics by circling the correct answers.

   a. Job opportunities result each year from the need to replace (**inexperienced, experienced**) mechanics who are promoted, retired, or transferred to related fields of work.

   b. The number of diesel engine applications (**increases, decreases**) each year.

   c. Demand for diesel power has increased due to the added economy, endurance, and (**low, high**) efficiency of the diesel engine as compared to other power units.

3. Select the places that employ diesel mechanics by placing an "X" in the appropriate blanks.

   _____a. Sales agencies and manufacturers of diesel engines

   _____b. Motorcycle sales agencies

   _____c. Lawnmower repair shop

   _____d. Independent repair shops

   _____e. Electric power plants

   _____f. Service departments of dealers and distributors

   _____g. Railroad locomotive shops

   _____h. Fuel injection repair station

   _____i. Oil fields

   _____j. Agriculture

4. Complete requirements for entry into the diesel mechanics program by circling the correct answer.

   a. Operate the shop equipment (**correctly, incorrectly**).

   b. Be safety conscious; follow (**safety, hunting**) regulations.

   c. Take (**instructions, breaks**) readily; follow directions.

   d. Have (**enthusiasm, no enthusiasm**) about work.

   e. Be (**conscious, unconscious**) of waste in materials and man-hours.

TEST

5. List five diesel engine applications.

a. ____

b. ____

c. ____

d. ____

e. ____

6. Match the colors of the safety color code on the right with the correct applications.

______a. Designates caution and marks physical hazards

______b. Identifies the location of fire fighting equipment and apparatus

______c. Designates safety and the location of first aid equipment

______d. Designates dangerous parts of equipment which may cut, crush, shock, or otherwise injure

______e. Designates caution against starting equipment while it is being worked upon, or against the use of defective equipment

______f. Designates traffic and housekeeping markings

______g. Designates radioactive material

1. Black, white, or combinations of black and white
2. Blue
3. Green
4. Orange
5. Purple
6. Red
7. Yellow

7. Complete a list of personal safety rules by circling the correct answer.

a. Wear shop clothing and (**work, tennis**) shoes appropriate to the activity being performed.

b. Confine (**short, long**) hair at all times.

c. Always wear (**respirators, eye protection**) when in the shop area, and as required by school policy.

d. Confine loose clothing such as ties when working around (**machine, hand**) tools or rotating equipment.

TEST

e. Remove jewelry, rings, earrings, necklaces when working in the (**shop, classroom**).

f. Conduct yourself in a manner conducive to (**safe, unsafe**) shop practices.

8. Select true statements concerning personal safety rules by placing an "X" beside the true statements.

_____a. Keep all hand tools clean and work area in safe working order.

_____b. Report any defective tools, machines, and equipment to your best friend.

_____c. Remove all guards and safety devices.

_____d. Operate powered equipment only after receiving instruction on how to operate the machine safely.

_____e. Report all accidents to the superintendent.

_____f. Turn off the power before leaving a machine tool.

_____g. Make sure all guards and barriers are removed or misadjusted before starting a machine tool.

_____h. Disconnect the power from machine tools before performing any maintenance task.

_____i. Use a solvent only after determining its properties, what kind of work it has to do, and how to use it.

_____j. Use correct type and proper size of files for nuts, bolts, and objects to be turned or held.

_____k. Keep the shop or laboratory floor clear of tools, scraps, and litter.

_____l. Clean up any spilled liquids at the end of the day.

_____m. Store oily rags or oily waste in paper containers.

_____n. Clean the chips from a machine with a brush; do not use a rag or bare hands.

_____o. Use proper support for all heavy objects.

_____p. Practice tool motto: "Get, use, and put away."

TEST

9. Match possible sources of accidents on the right with the injury which may occur.

______a. Serious injuries to eyes and skin may be caused by high air pressure

______b. One blast may rip clothing or skin

______c. May cause eye or face injury from flying sparks or metal chips

______d. May explode when near open flame or electrical spark

______e. Can cause injury to eyes and to skin if protective equipment is not worn

______f. May catch in rotating parts

______g. Sharp edges may puncture skin

______h. May cause shock if not grounded

______i. A fall may cause a fatal injury

______j. May cause severe back injury

______k. May cause others to fall against sharp objects or moving machinery

______l. May catch fingers or clothing

1. Air hose
2. Batteries
3. Electrical power tools
4. Grinder
5. Horseplay
6. Lack of or improper supporting device under heavy objects
7. Lifting heavy objects
8. Loose clothing
9. Moving parts
10. Pneumatic tools
11. Tools
12. Welding

10. Match the four classes of fire on the right with the correct statements defining each class.

______a. Fires that occur in ordinary combustible materials

______b. Fires that occur with flammable liquids

______c. Fires that occur in or near electrical equipment

______d. Fires that occur in combustible metals

1. Class A
2. Class B
3. Class C
4. Class D

TEST

11. Match the types of fire extinguishers on the right with the class of fire they are used on.

    ______a. Class A

    ______b. Class B

    ______c. Class C

    1. Carbon dioxide

    2. Dry chemical

    3. Pressurized water

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

12. Compile a list of employment opportunities in diesel mechanics in your community. (Assignment Sheet #1)

13. Write a resume. (Assignment Sheet #2)

14. Complete an employment application form. (Assignment Sheet #3)

15. Complete a safety pledge form. (Assignment Sheet #4)

16. Complete an individual student shop safety inspection. (Assignment Sheet #5)

INTRODUCTION TO DIESEL MECHANICS AND SHOP SAFETY
UNIT I-A

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 7
   d. 9
   e. 8
   f. 2
   g. 11
   h. 12
   i. 10
   j. 1
   k. 4
   l. 6

2. a. Experienced
   b. Increases
   c. High

3. a, d, e, f, g, h, i, j

4. a. Correctly
   b. Safety
   c. Instructions
   d. Enthusiasm
   e. Conscious

5. Any five of the following:

   a. Electric power plants
   b. Marine engines
   c. Farm tractors and equipment
   d. Road building equipment
   e. Automotive vehicles
   f. Rail locomotives
   g. Construction equipment

6. a. 7
   b. 6
   c. 3
   d. 4
   e. 2
   f. 1
   g. 5

ANSWERS TO TEST

7.
   a. Work
   b. Long
   c. Eye protection
   d. Machine
   e. Shop
   f. Safe

8. a, d, f, h, i, k, n, o, p

9.
   a. 10
   b. 1
   c. 4
   d. 2
   e. 12
   f. 8
   g. 11
   h. 3
   i. 6
   j. 7
   k. 5
   l. 9

10.
   a. 1
   b. 2
   c. 3
   d. 4

11.
   a. 3, 2
   b. 1, 2
   c. 1, 2

12.-16. Evaluated to the satisfaction of the instructor

BASIC SHOP TOOLS
UNIT II-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify and choose the right tool for the job and maintain tools in a safe condition. The student should also be able to repair and sharpen certain tools and to accurately read measuring instruments. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Identify basic shop tools.
2. Identify types of screwdrivers.
3. Name two types of hammers.
4. Identify types of pliers.
5. Identify types of wrenches.
6. Identify types of cold chisels.
7. Identify types of punches.
8. Identify types of file teeth.
9. Identify types of pullers.
10. Identify types of feeler gauges.
11. Match types of taps with their functions.

OBJECTIVE SHEET

12. Identify types of micrometers.
13. Identify ways to extract a screw.
14. Identify principal parts of a twist drill.
15. Name shop tools used for measuring shaft speed.
16. Distinguish between correct and incorrect methods of using and maintaining basic shop tools.
17. Name precautions for correct use of the hacksaw.
18. Read micrometer settings. (Assignment Sheet #1)
19. Read vernier micrometer settings. (Assignment Sheet #2)
20. Demonstrate the ability to:
    a. Sharpen a twist drill. (Job Sheet #1)
    b. Drill holes with a drill press. (Job Sheet #2)
    c. Sharpen a cold chisel. (Job Sheet #3)
    d. Dress a grinding wheel. (Job Sheet #4)
    e. Check a torque wrench for accuracy. (Job Sheet #5)
    f. Tin a soldering gun. (Job Sheet #6)
    g. Use a file. (Job Sheet #7)
    h. Use the outside micrometer. (Job Sheet #8)
    i. Use the vernier caliper to take inside, outside, and depth measurements. (Job Sheet #9)
    j. Use the depth micrometer. (Job Sheet #10)
    k. Use a dial indicator. (Job Sheet #11)
    l. Use a cylinder bore gauge. (Job Sheet #12)
    m. Use the telescoping gauge. (Job Sheet #13)

BASIC SHOP TOOLS
UNIT II-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Take students into shop and show hand tools.
2. Have students inventory the tool box they will use.
3. Have students make a list of beginning tools.
4. Have students make a list of special tools.
5. Show film on tool safety.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Dagel, John F. *Diesel Engine Repairs.* New York: John Wiley and Sons, Inc., 1982.

B. *Fundamentals of Service: Shop Tools.* 3rd ed. Moline, IL: Deere and Company, 1980.

C. Krar, Stephen F. *Technology of Machine Tools.* New York: Gregg Division/McGraw-Hill Book Company, 1977.

REFERENCES USED IN DEVELOPING THIS UNIT

D. Schulz, Erich J. *Diesel Mechanics.* 2nd ed. New York: Gregg Division/McGraw-Hill Book Company, 1983.

E. *Snap-on Catalog.* Kenosha, WI: Snap-on Tools Corp., 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Filmstrips**

1. *Shop Tools* (3rd edition)

John Deere Service Training
John Deere Road
Moline, IL 61265

Contains 36 pages with 84 two-color illustrations (F05-51038)
Slide set: 47 slides in 35mm color in standard 2×2-inch frames (F05-51035)

2. *Safety In The Shop: Hand Tools*, color, 14 minutes

(NOTE: This film shows how to safely handle and properly maintain the following tools: saws, chisels, screwdrivers, wrenches, and welding torch.)

Coronet Films
65 E. South Water Street
Chicago, IL 60601
1 800 621-2131

B. **Texts**

1. *Automotive Tools and Equipment*

Brodhead-Garrett Company
4560 East 71st Street
Cleveland, OH 44105
1 800 321-6730

2. *Equipment Shop Supplies*

M & L Motor Supply Company
1493 University Avenue
St. Paul, MN 55104
(612) 645-8661

3. *Common tools*

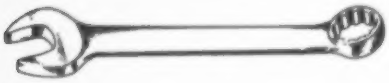
Caterpillar Service Training
600 W. Washington Street
East Peoria, IL 61630

BASIC SHOP TOOLS
UNIT II-A

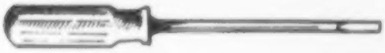
INFORMATION SHEET

I. **Basic shop tools**

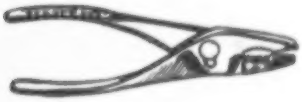
A. Combination box and open end wrench



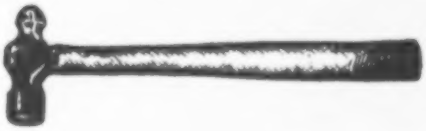
B. Common screwdriver



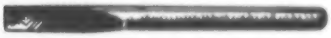
C. Slip joint pliers



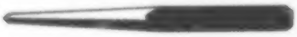
D. Ball peen hammer



E. Flat cold chisel

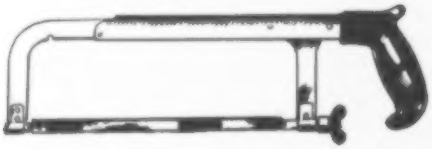


F. Center punch

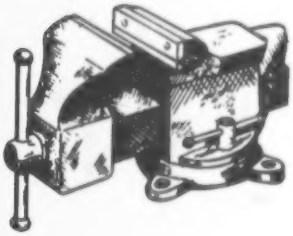


G. Flat file

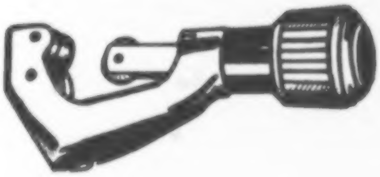
H. Hacksaw



I. Vise

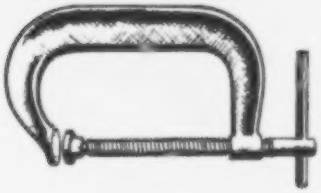


J. Tubing cutter

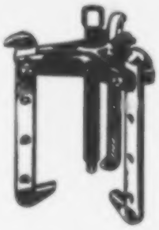


INFORMATION SHEET

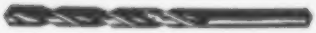
K. "C" clamp



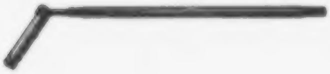
L. External puller



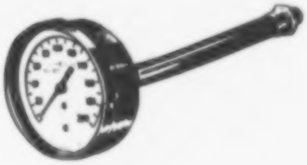
M. Twist drill



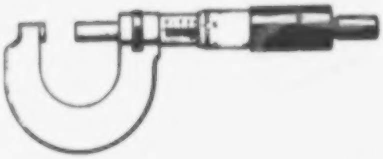
N. Magnetic pick-up tool



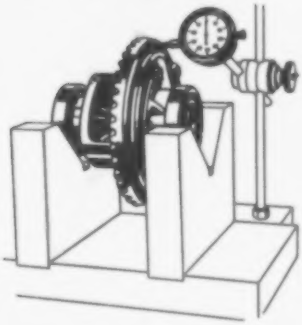
O. Pressure gauge (oil pressure)



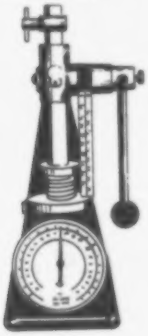
P. Outside micrometer



Q. Dial indicator

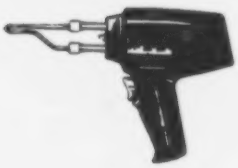


R. Spring tester

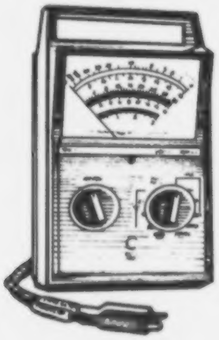


INFORMATION SHEET

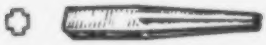
S. Soldering gun



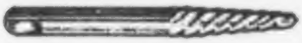
T. Multimeter



U. Screw extractor

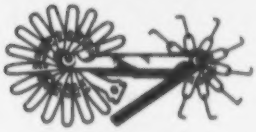


(square)

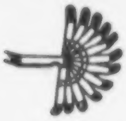


(spiral flute)

V. Feeler gauge

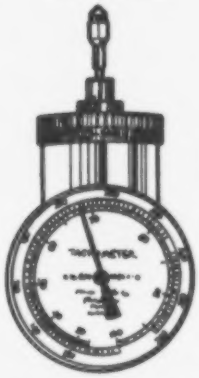


(straight wire)



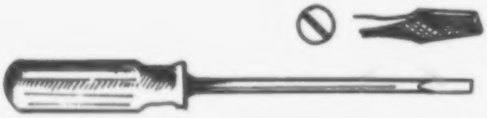
(offset)

W. Tachometer

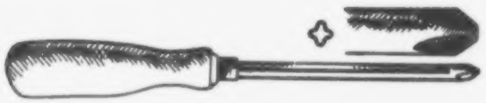


II. Types of screwdrivers

A. Common

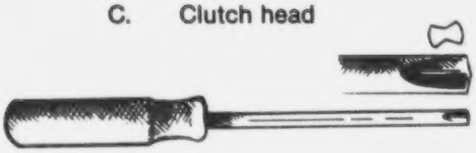


B. Phillips head

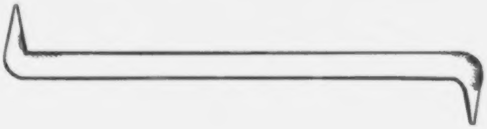


INFORMATION SHEET

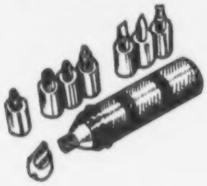
C. Clutch head



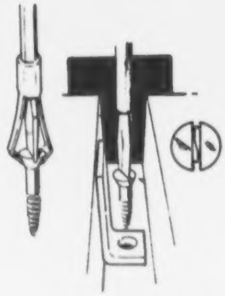
D. Offset



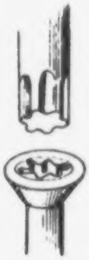
E. Impact screwdriver



F. Starting screwdriver



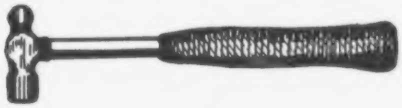
G. Torx



III. **Types of hammers**

(NOTE: There are many sizes and weights of hammers.)

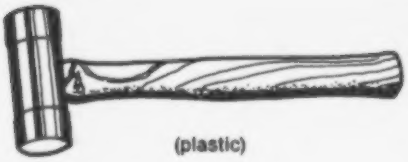
A. Ball peen



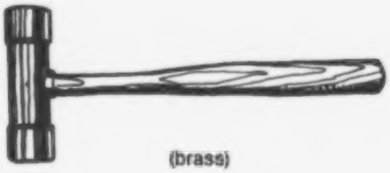
INFORMATION SHEET

B. Soft face

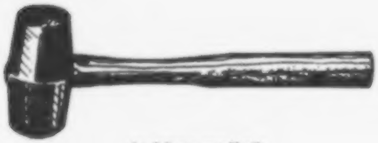
Examples:



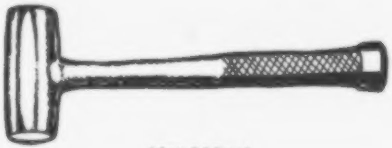
(plastic)



(brass)



(rubber mallet)

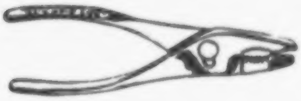


(dead blow)

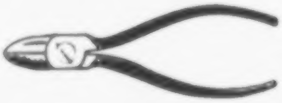
(NOTE: Dead blow hammers are usually a one-piece plastic hammer with shot in the head.)

IV. **Types of pliers**

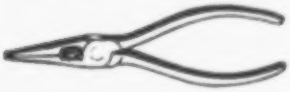
A. Slip joint



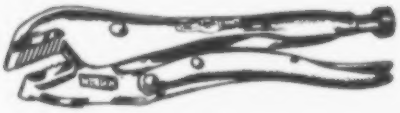
B. Diagonal cutters



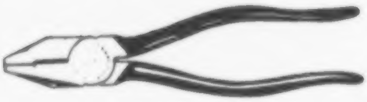
C. Needle nose



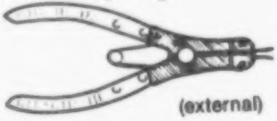
D. Lock grip



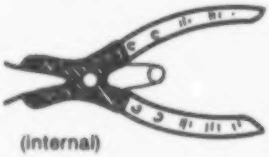
E. Side cutters



F. Snap ring



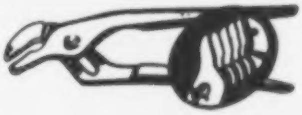
(external)



(internal)

INFORMATION SHEET

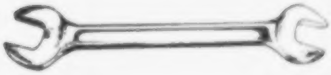
G. Channel lock



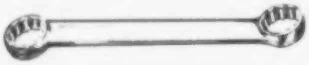
(NOTE: There are other specialized pliers that are used on certain applications, and you will become familiar with them later.)

V. **Types of wrenches**

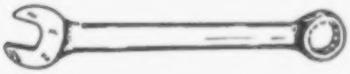
A. Open end



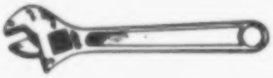
B. Box



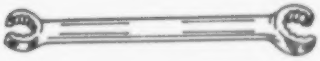
C. Combination



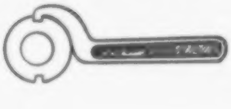
D. Adjustable



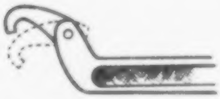
E. Tubing (line)



F. Hook spanner



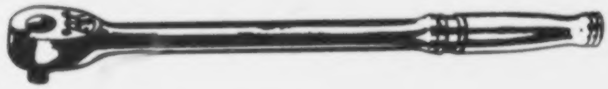
G. Adjustable hook spanner



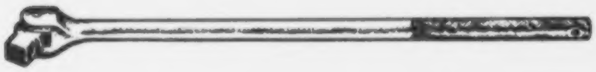
INFORMATION SHEET

H. Socket wrenches and handles

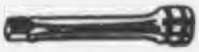
1. Ratchet handle



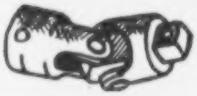
2. Flex handle (breakover)



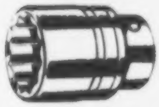
3. Extension



4. Universal joint

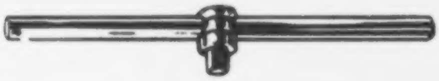


5. Socket

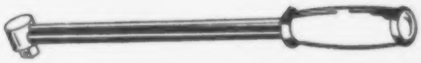


(NOTE: The sockets may be six point, twelve point, or deepwell.)

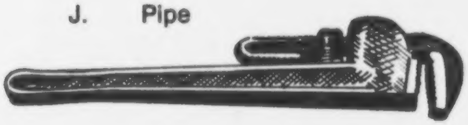
6. Sliding "T" handle



I. Torque

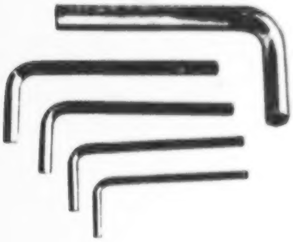


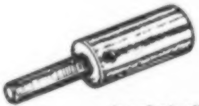
J. Pipe



INFORMATION SHEET

K. Allen

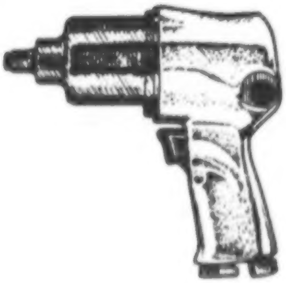




(socket allen)

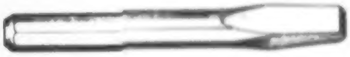
(NOTE: Allen wrenches are available in standard and metric sizes.)

L. Air impact

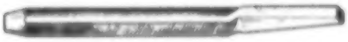


VI. Types of cold chisels

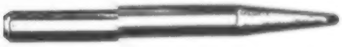
A. Flat



B. Cape



C. Round nose

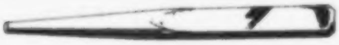


D. Diamond point

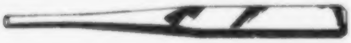
INFORMATION SHEET

VII. Types of punches

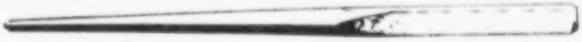
A. Starting



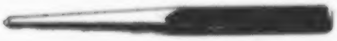
B. Pin



C. Aligning

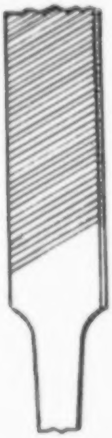


D. Center

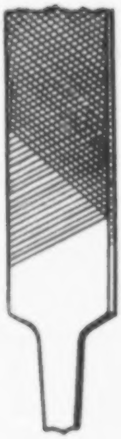


VIII. Types of file teeth

A. Single cut

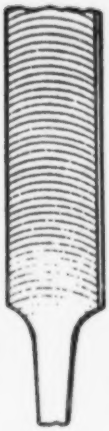


B. Double cut

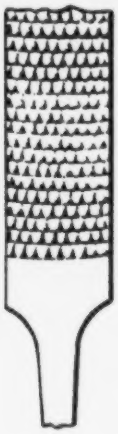


INFORMATION SHEET

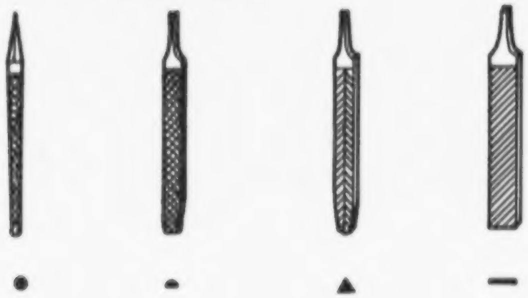
C. Curved tooth



D. Rasp cut

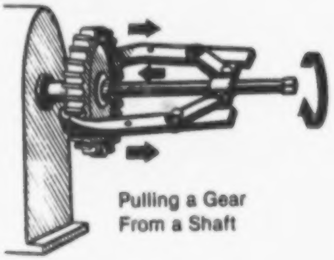


(NOTE: Files are made in numerous sizes and shapes. Common shapes are round, half round, flat, and triangle.)

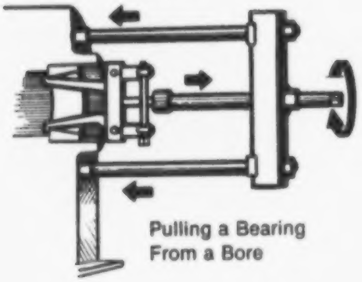


IX. Types of pullers

A. External

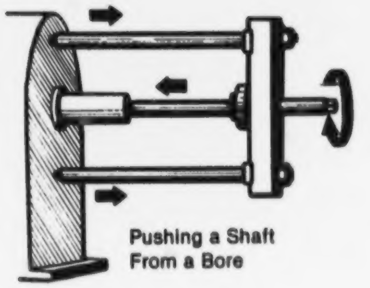

Pulling a Gear
From a Shaft

B. Internal

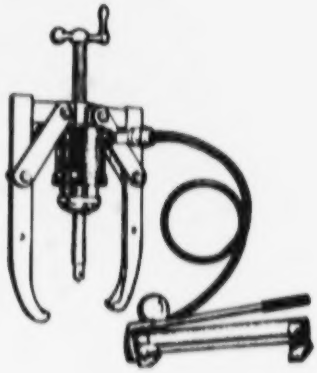

Pulling a Bearing
From a Bore

INFORMATION SHEET

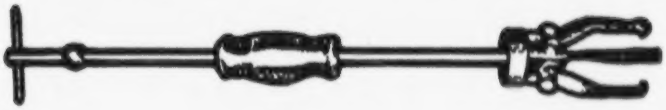
C. Press


Pushing a Shaft
From a Bore

D. Hydraulic

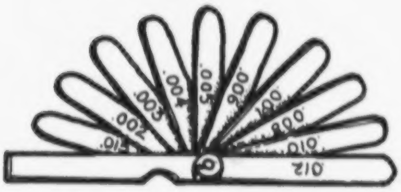


E. Slide hammer



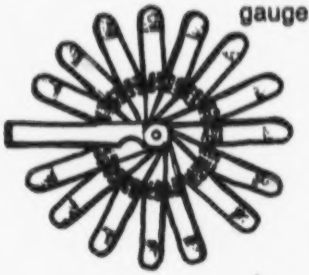
X. Types of feeler gauges

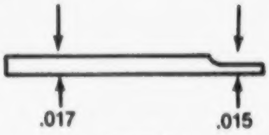
A. Standard


.002
.003
.004
.005
.006
.007
.008
.010
.012
.015

B. Stepped

(NOTE: This is also known as go-no-go gauge.)

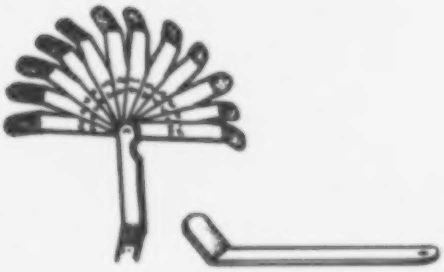




Example

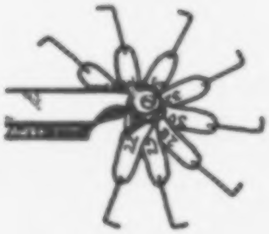
INFORMATION SHEET

C. Bent



Example

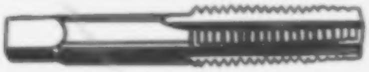
D. Wire



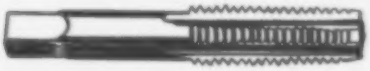
XI. Types of taps and their functions

(NOTE: Taps are used for cutting internal threads.)

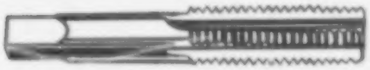
A. Taper—Used to start the thread



B. Plug—Used after taper tap has cut the threads as far as possible



C. Bottoming—Used last to cut the thread to the bottom of the hole (if necessary)

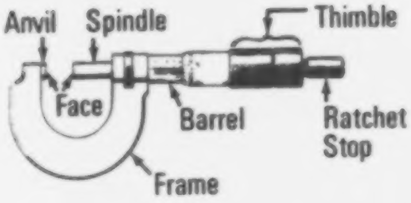


(NOTE: Taps are also available in metric and national pipe thread sizes.)

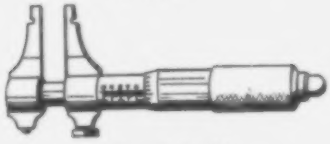
INFORMATION SHEET

XII. Types of micrometers

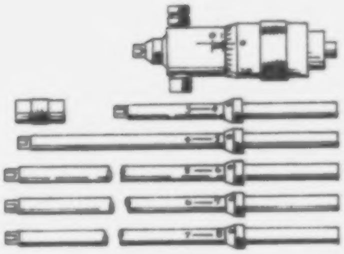
A. Outside


Anvil
Spindle
Thimble
Face
Barrel
Ratchet Stop
Frame

B. Inside

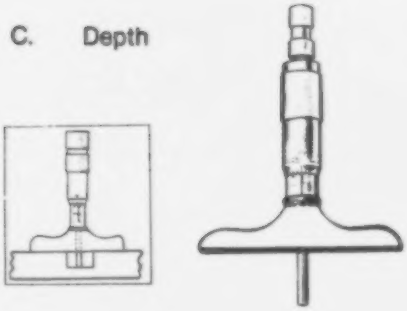


Small Inside

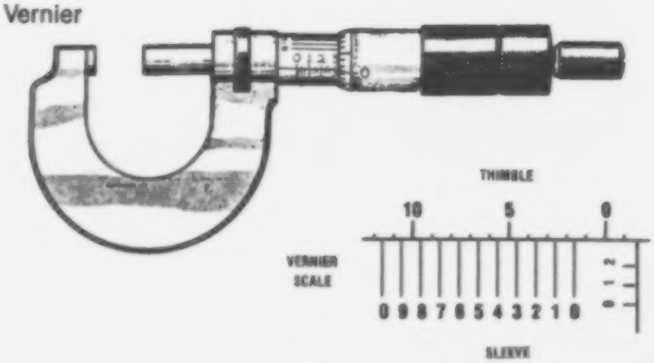


Large Inside

C. Depth

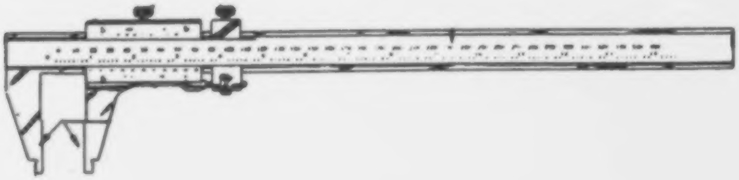


D. Vernier


THIMBLE
10
5
0
VERNIER SCALE
0 9 8 7 6 5 4 3 2 1 0
0 1 2
SLEEVE

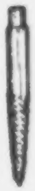
INFORMATION SHEET

E. Vernier caliper

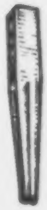


XIII. Ways to extract a screw

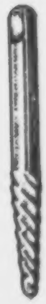
A. Screw extractor ("easy-out")



Fine
Left-Hand
Twist



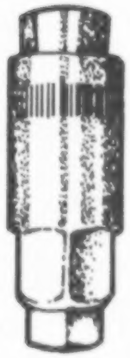
Square



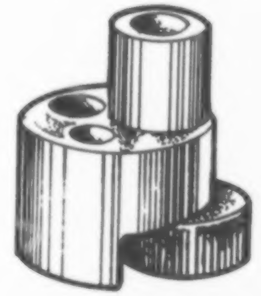
Coarse
Left-Hand
Twist

INFORMATION SHEET

B. Stud puller

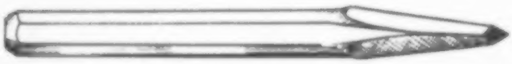


(collet-type)



(wedge-type)

C. Diamond point chisel

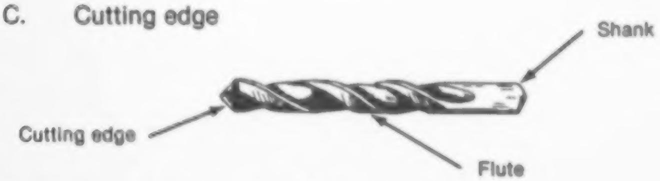


XIV. Principal parts of twist drill

A. Shank

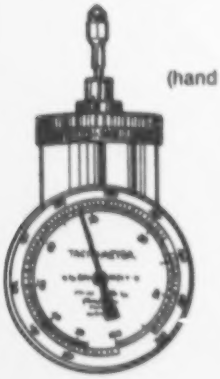
B. Flute

C. Cutting edge

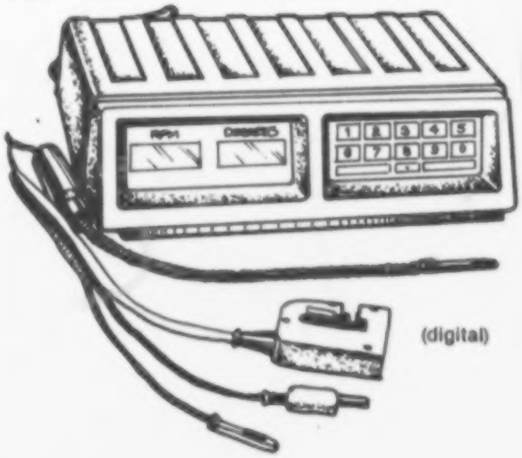

Shank
Cutting edge
Flute

XV. Tools used for measuring shaft speed

A. Tachometer



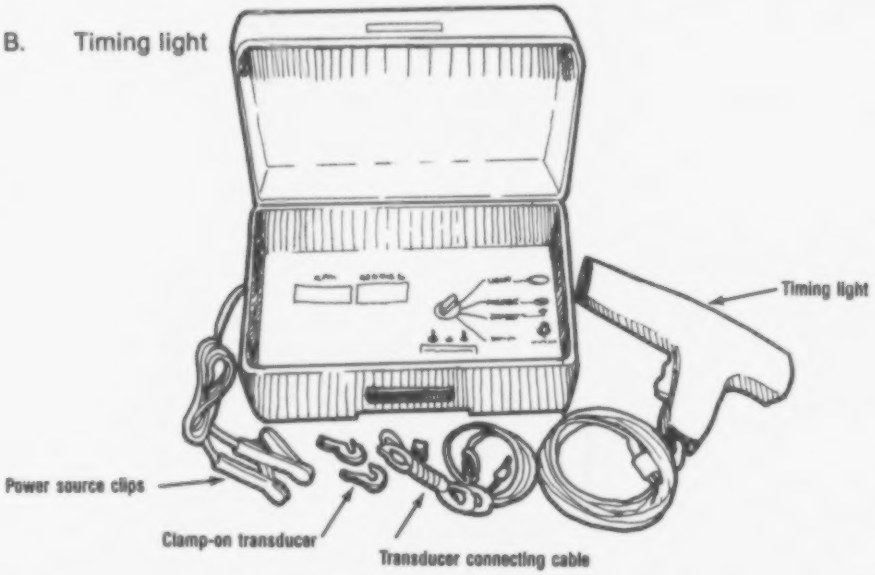
(hand held)



(digital)

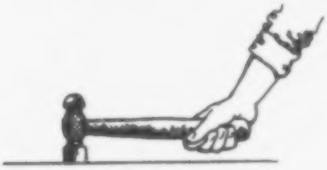
INFORMATION SHEET

B. Timing light

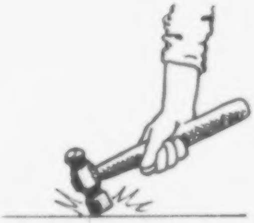

Timing light
Power source clips
Clamp-on transducer
Transducer connecting cable

XVI. Correct and incorrect methods of using and maintaining basic shop tools

A. Hammer

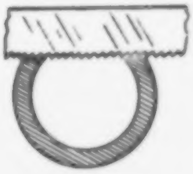


Right

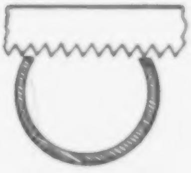


Wrong

B. Hacksaw blade



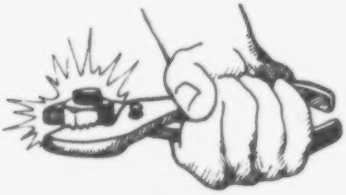
Right Blade



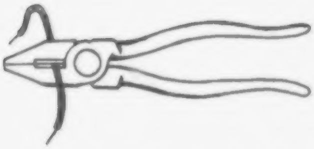
Wrong Blade

INFORMATION SHEET

C. Pliers

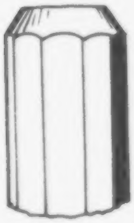


Don't Use Pliers on Nuts

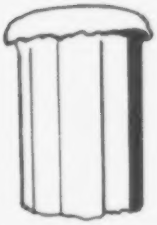


Use Side Cutters to Cut Wire

D. Cold chisel

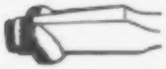


Right

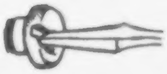


Wrong

E. Screwdriver

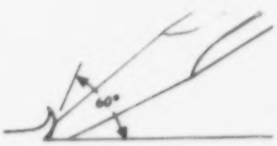


Right

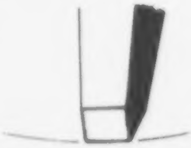


Wrong

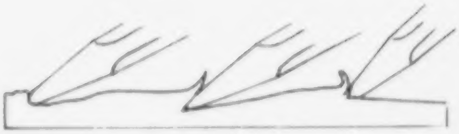
F. Grinding flat cold chisel



Correct Angle 60°



Round Edge Slightly



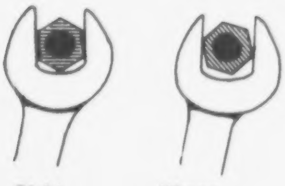
Rounded and Dull

Angle is too Small

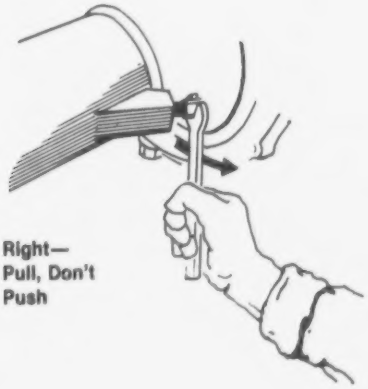
Angle is too Large

INFORMATION SHEET

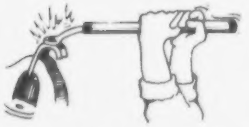
G. End wrench



Right **Wrong**

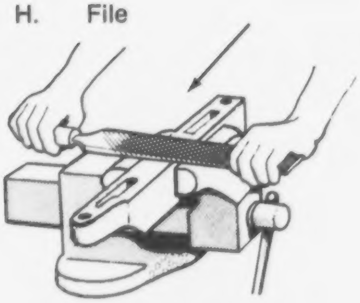


Right— Pull, Don't Push

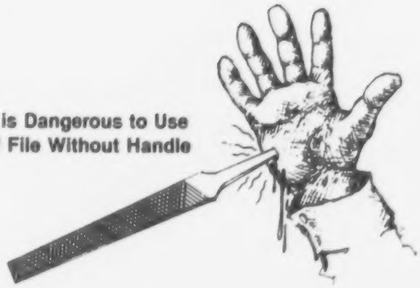


Wrong—Never Use a Bar or a Pipe on a Wrench

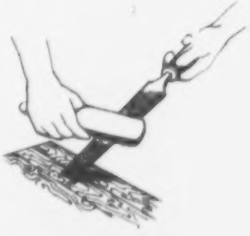
H. File



Correct Method of Draw-Filing



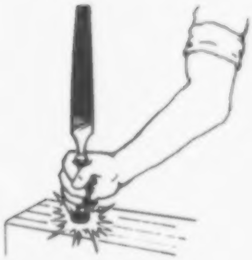
It is Dangerous to Use of File Without Handle



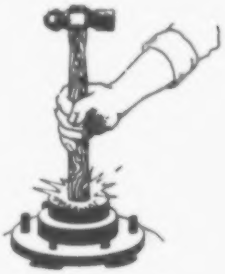
Correct Method of Cleaning a File

INFORMATION SHEET

I. File and hammer handles



Correct Method of
Tightening File Handle



Incorrect Use of
a Hammer

XVII. Precautions for correct use of hacksaw

A. Teeth must point away from handle.

B. Blade must be tightly stretched.

C. Select blade with correct number of teeth per inch for material being cut.

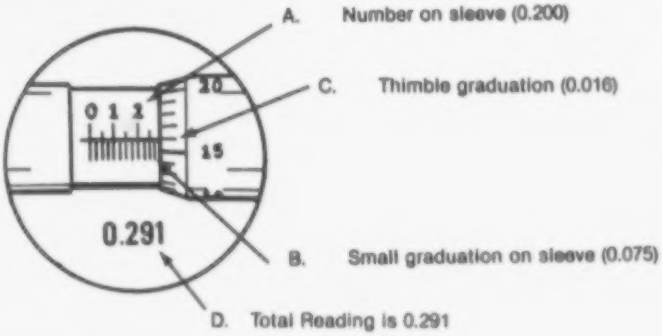
(NOTE: Two teeth should always be contacting the material being cut.)

D. Use sufficient pressure on the forward stroke.

E. Use full length of blade on each stroke.

(CAUTION: Do not operate saw with excessive amount of pressure or speed.)

XVIII. Reading the micrometer (Transparencies 1, 2, and Overlay 2A)


A. Number on sleeve (0.200)
C. Thimble graduation (0.016)
0 1 2
20
15
0.291
B. Small graduation on sleeve (0.075)
D. Total Reading is 0.291

INFORMATION SHEET

A. Each numbered graduation on the sleeve represents one hundred thousandths of an inch (0.100").

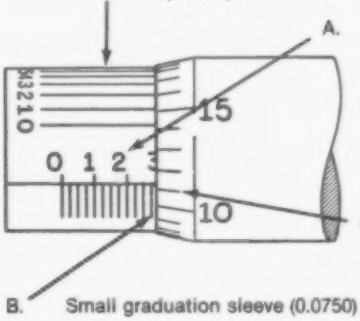
B. Each small graduation on the sleeve between the numbered graduations represents two-five thousandths of an inch (0.025").

C. Each graduation found on the thimble represents one thousandth of an inch (0.001").

D. Total reading is found by adding the three values.

Example:		
	0.200	Number on the sleeve
	0.075	Small graduations on the sleeve
	0.016	Graduations on the thimble
	0.291	Micrometer reading

XIX. **Reading the vernier micrometer** (Transparencies 2, 3, and Overlays 2A and 3A)



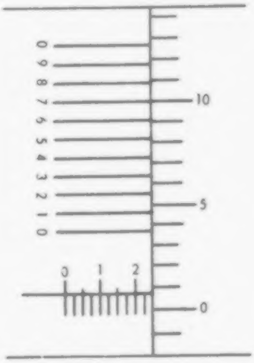
D. Vernier Scale Graduation on top of sleeve (0.0002)

A. Number on sleeve (0.2000)

C. Thimble graduation (0.0110)

B. Small graduation sleeve (0.0750)

E. Total reading is 0.2862



0.2507"

A. Each numbered graduation on the sleeve represents one hundred thousands of an inch (0.100").

B. Each small graduation on the sleeve between the numbered graduations represents twenty-five thousandths of an inch (0.025").

C. Each graduation found on the thimble represents one thousandth of an inch (0.001").

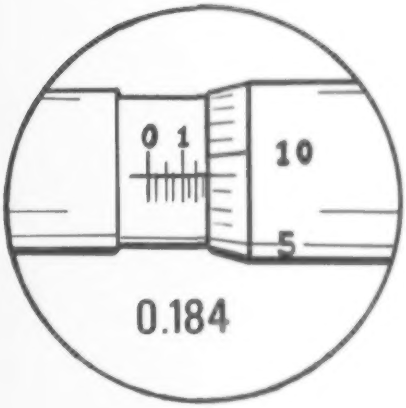
D. Each line graduation found on top of the sleeve represents one ten-thousandth of an inch (0.001").

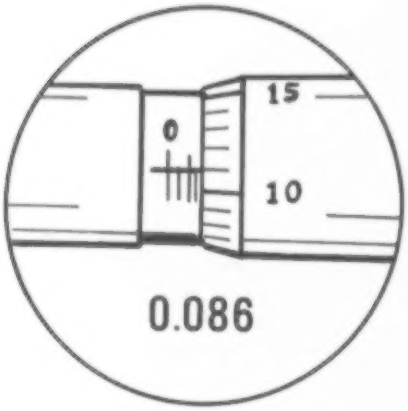
INFORMATION SHEET

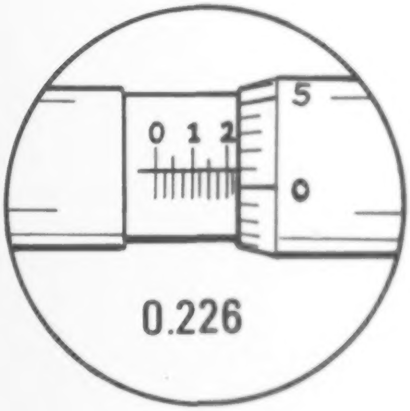
E. Total reading is found by adding the four values.

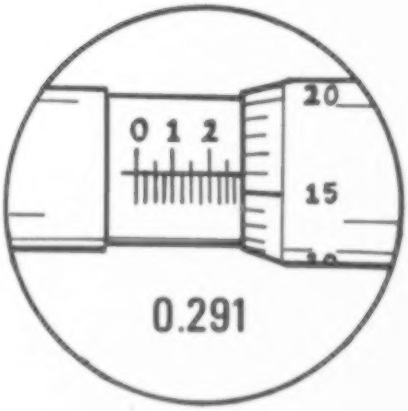
Example:	0.2000	Number on the sleeve
	0.0750	Small graduations on the sleeve
	0.0110	Graduations on the thimble
	0.0002	Vernier scale on top of sleeve
	0.2862	Vernier micrometer reading

Reading a Micrometer

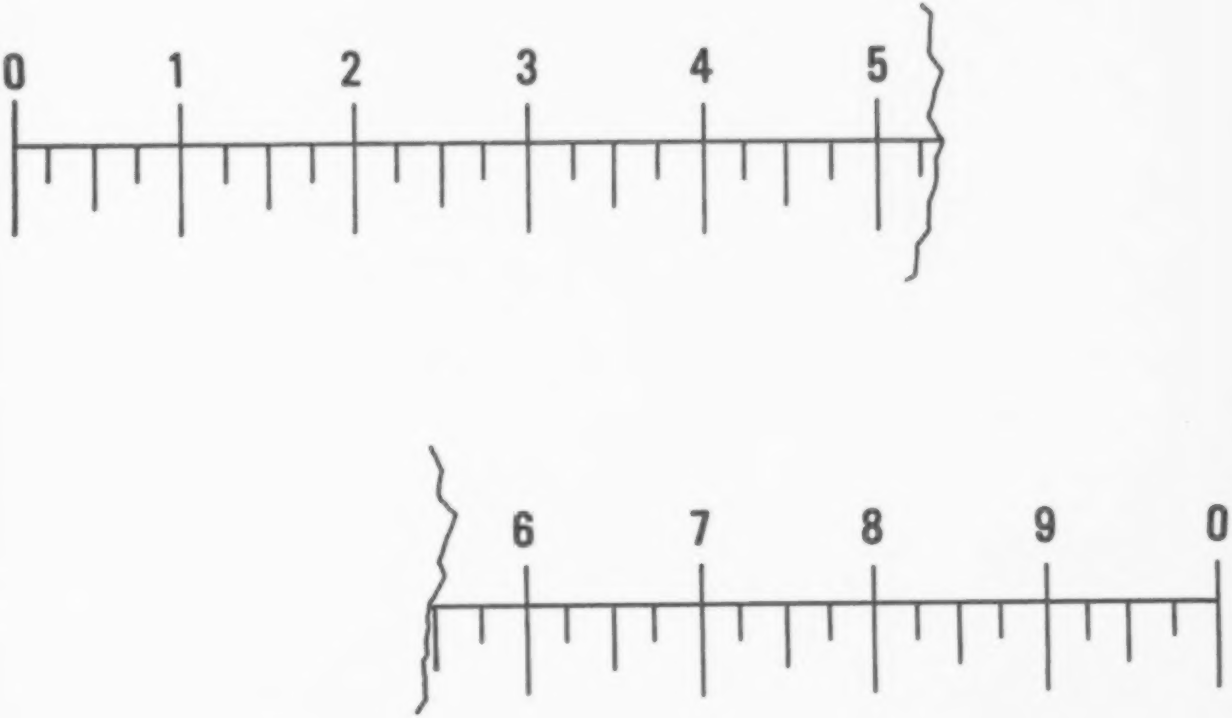




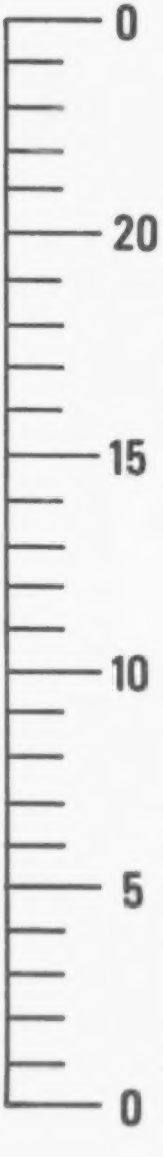



0 1 2
20
15
0.291

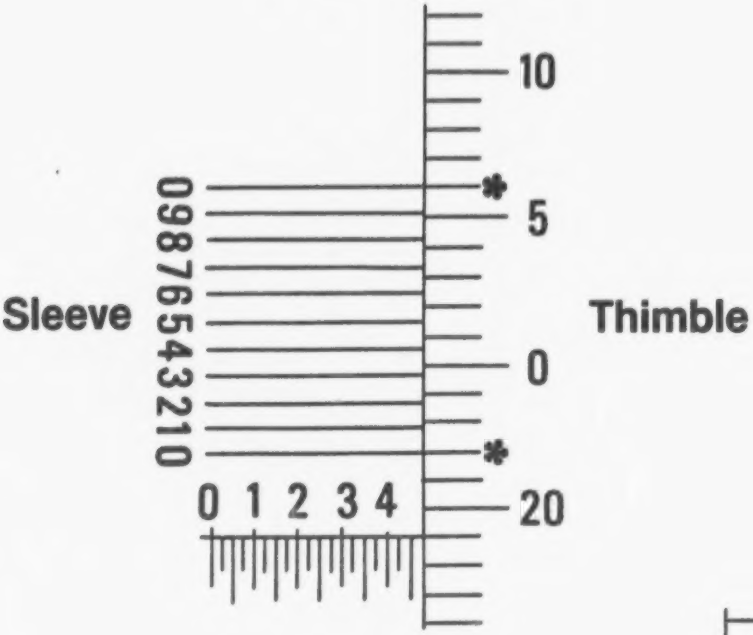
Sleeve Readings


0
1
2
3
4
5
6
7
8
9
0

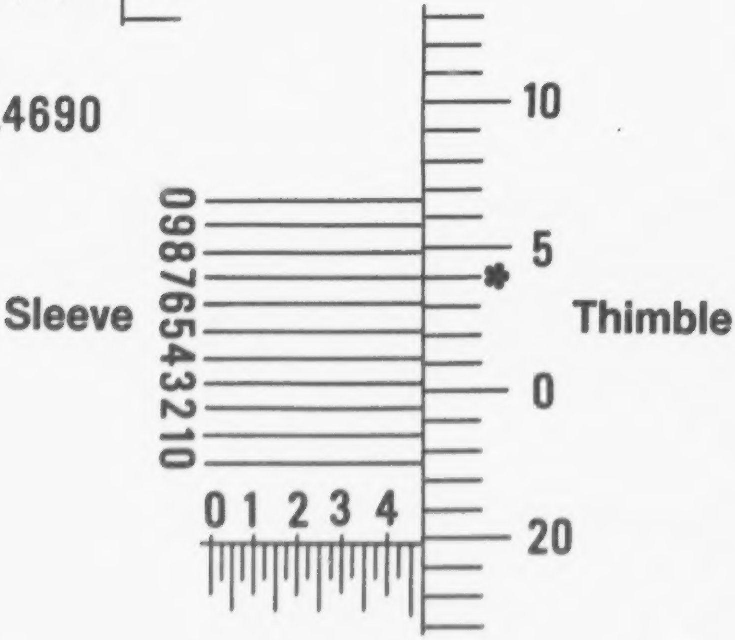
Thimble Sleeve Readings



Vernier Micrometer Readings

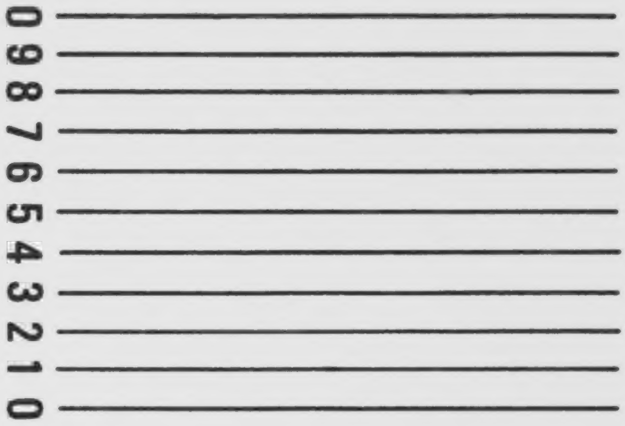

Sleeve
Thimble
0987654321 0
0 1 2 3 4
10
5
0
20
*

0.4690


Sleeve
Thimble
0987654321 0
0 1 2 3 4
10
5
0
20
*

0.4697

Vernier Sleeve Readings

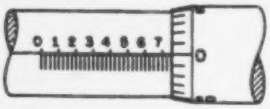

0
9
8
7
6
5
4
3
2
1
0

BASIC SHOP TOOLS
UNIT II-A

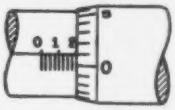
ASSIGNMENT SHEET #1 — READ THE MICROMETER SETTINGS

NAME ____________________________ SCORE ____________________________

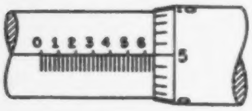
Directions: Read the micrometer settings below and write the correct answers in the blanks provided.



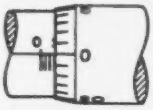
1. ____________________________________



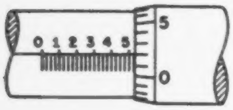
2. ____________________________________



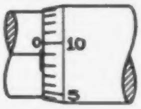
3. ____________________________________



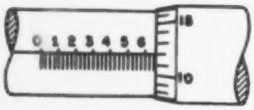
4. ____________________________________



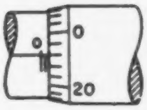
5. ____________________________________



6. ____________________________________


0 1 2 3 4 5 6
15
10

7. ____________________________________



8. ____________________________________

BASIC SHOP TOOLS
UNIT II-A

ASSIGNMENT SHEET #2 — READ THE VERNIER MICROMETER SETTINGS

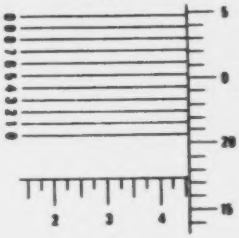
NAME ______________________ SCORE ______________________

Directions: Read the vernier micrometer settings below and write the correct answers in the blanks provided.

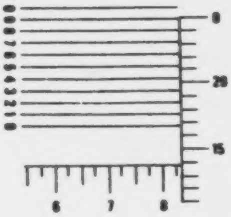
Answers

1. ________
2. ________
3. ________
4. ________
5. ________
6. ________
7. ________
8. ________
9. ________
10. ________

1.


0 9 8 7 6 5 4 3 2 1 0
5
0
20
15
2
3
4

2.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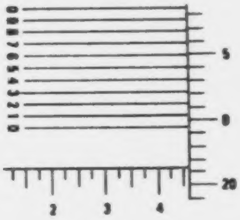
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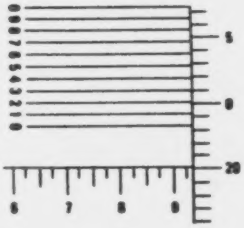
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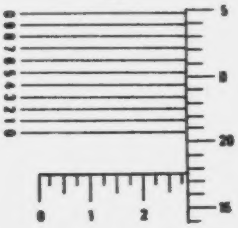
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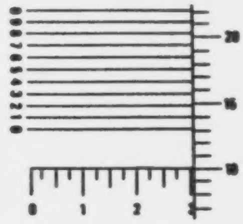
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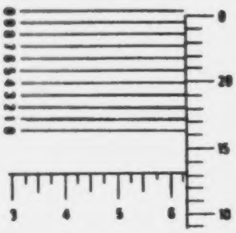
3

7.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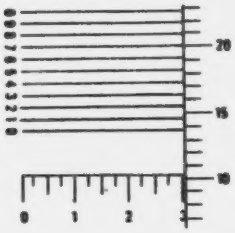
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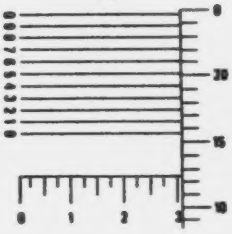
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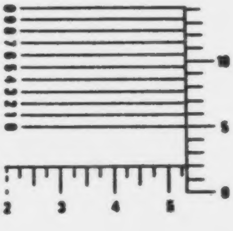
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0
2
3
4
5

BASIC SHOP TOOLS
UNIT II-A

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 0.750
2. 0.201
3. 0.655
4. 0.075
5. 0.527
6. 0.009
7. 0.662
8. 0.048

Assignment Sheet #2

1. 0.4678
2. 0.8388
3. 0.4715
4. 0.9453
5. 0.2928
6. 0.3101
7. 0.6383
8. 0.3107
9. 0.3128
10. 0.5270

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #1 — SHARPEN A TWIST DRILL

A. Tools and materials

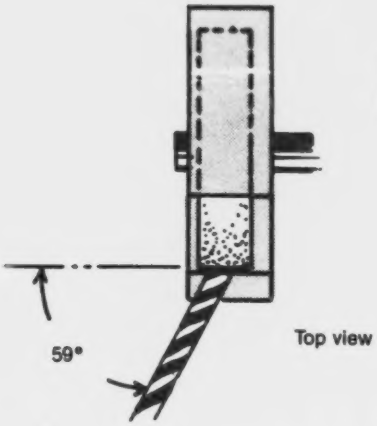
1. Safety goggles or eye protection
2. Grinder
3. Twist drill
4. Container of water

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Place the drill point against the grinding wheel at approximately a 59° angle. (Figure 1)

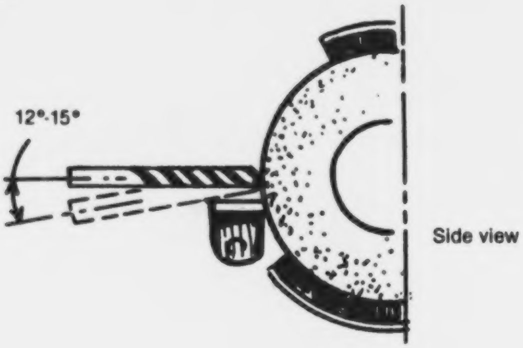
FIGURE 1



JOB SHEET #1

2. Using both hands, lower the shank, and raise the bit cutting point against the wheel. (Figure 2)

FIGURE 2



3. Rotate the bit in a clockwise manner while grinding.

4. Grind both lips in the same manner.

5. Dip the point in water frequently to keep it cool.

   (CAUTION: Watch for coloration on tip of drill; if tip starts to turn blue, it is too hot.)

   (NOTE: Do not force drill bit too fast.)

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #2 — DRILL HOLES WITH A DRILL PRESS

A. Tools and materials

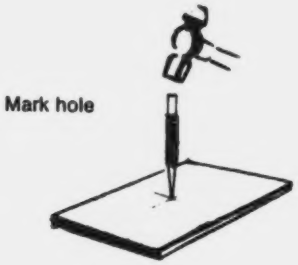
1. Safety goggles
2. Small piece of flat metal
3. Drill press
4. Center punch
5. Hammer
6. Wooden block
7. Cutting oil
8. Clamp
9. Measuring tool

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Measure to mark the hole with a center punch. (Figure 1)

FIGURE 1

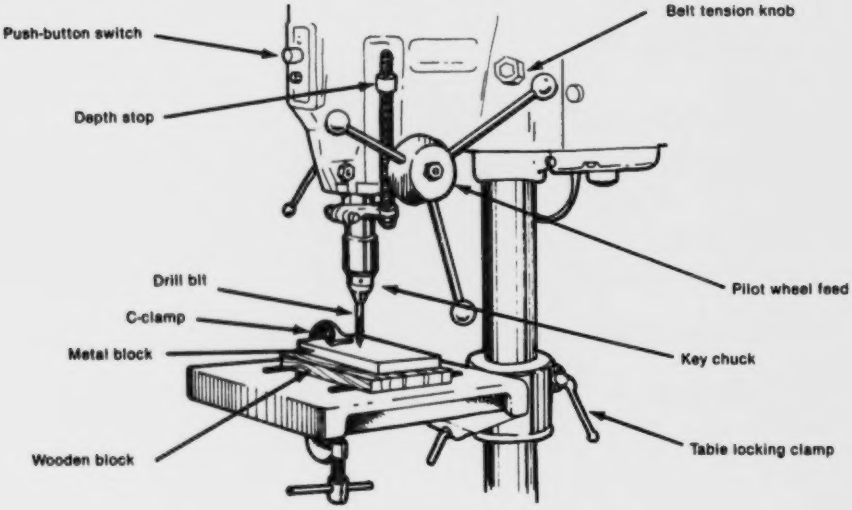


2. Place the metal on a wooden block.

JOB SHEET #2

3. Clamp the metal being drilled securely to prevent it from spinning. (Figure 2)

FIGURE 2


Push-button switch
Belt tension knob
Depth stop
Drill bit
Pilot wheel feed
C-clamp
Metal block
Key chuck
Wooden block
Table locking clamp

4. Select the correct drilling speed for the material. Feed the bit down to the metal and start drilling.

   (CAUTION: Select proper drill speed, if available.)

5. Raise the bit to see if you are drilling in the proper place.

6. Continue drilling, using cutting oil on the drill bit two or three inches above the work.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #3 — SHARPEN A COLD CHISEL

A. Tools and materials

1. Eye protection
2. Cold chisel
3. Grinder
4. Container of water

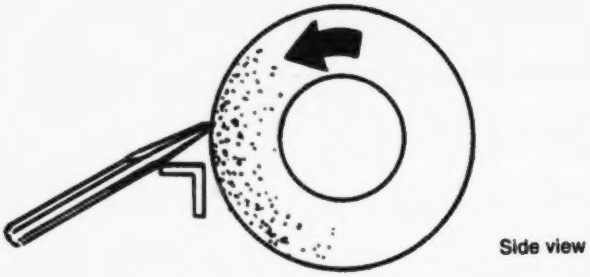
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Hold the chisel at a 65° to 70° angle with the handle pointing down. (Figure 1)

   (CAUTION: Check tool rest for proper adjustment.)

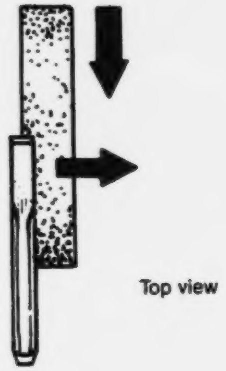
   FIGURE 1



JOB SHEET #3

2. Move the point from side to side across the grinding wheel. (Figure 2)

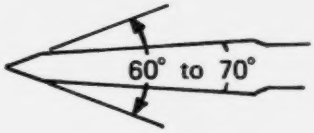
FIGURE 2



(NOTE: Dip the point in water frequently to keep it cool.)

3. Grind both sides of the cutting edge in the same manner. (Figure 3)

FIGURE 3



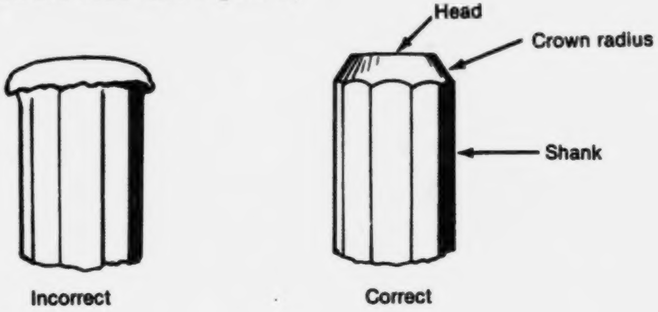
4. Dip the point in water frequently to keep it cool.

(NOTE: Do not allow tip to turn blue; it will be too hot.)

5. If the head had become mushroomed, it should be ground back into shape.

(NOTE: The head should be square with the shank, and the crown radius should taper away from the head. See Figure 4.)

FIGURE 4


Head
Crown radius
Shank
Incorrect
Correct

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #4 — DRESS A GRINDING WHEEL

A. Tools and materials

1. Eye protection
2. Grinding wheel on grinder
3. Dressing tool

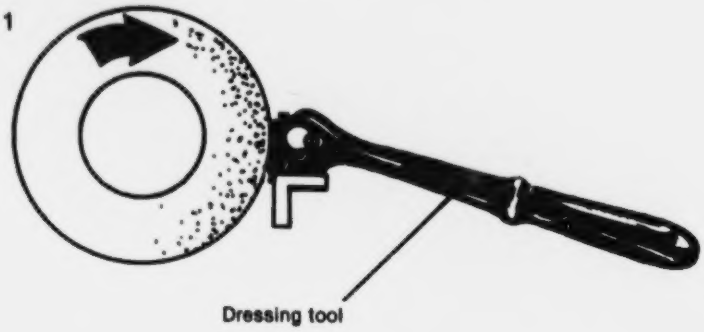
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Select the proper dressing tool.
2. Set the dressing tool on the grinder tool rest, and press it firmly against the wheel. (Figure 1)

   (NOTE: Use enough pressure on the tool to prevent sparks.)

FIGURE 1



3. Dress the grinder wheel with the tool until the edges are square with the sides.
4. Readjust tool rest to no more than ⅛" from grinding wheel.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #5 — CHECK A TORQUE WRENCH FOR ACCURACY

A. Tools and materials

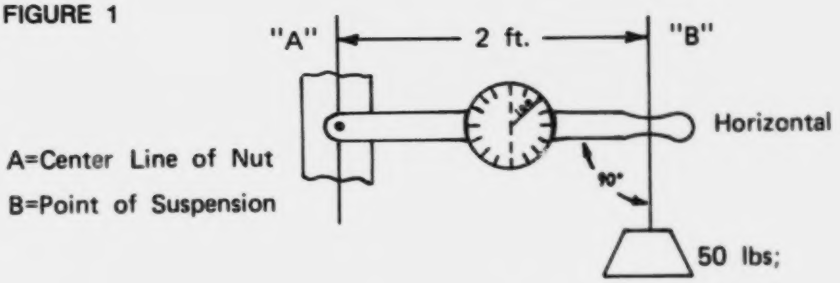
1. Torque wrench
2. Vise
3. "Known" weight
4. Strong cord

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Hang torque wrench on a fixed nut or secure in a vise. (Figure 1)

FIGURE 1


"A"
2 ft.
"B"
Horizontal
A=Center Line of Nut
B=Point of Suspension
90°
50 lbs;

2. Set the indicator to "0".
3. Hang a known weight from the wrench handle at any known distance from the center of the nut. (Figure 1)
4. Multiply the weight times the distance from A to B. (Figure 1)
5. Compare the answer to the indicator reading.

Example: In Figure 1, 50 pounds × 2 feet = 100 foot pounds

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #6 — TIN A SOLDERING GUN

A. Tools and materials

1. Safety glasses
2. Soldering gun

   (NOTE: The gun should have replaceable tips for use on different kinds of metals.)

3. Solder
4. Clean cloth

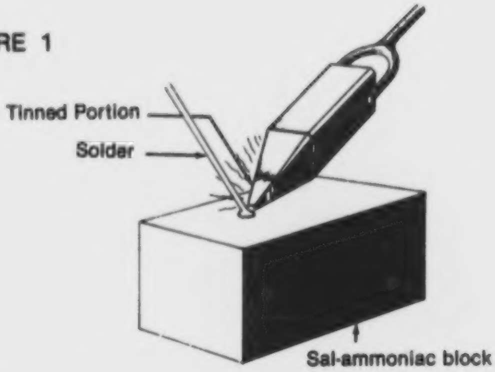
B. Procedure

(NOTE: Before a tip is used, it must be tinned — coated with a very thin film of solder.)

(CAUTION: Follow all shop safety procedures.)

1. Heat tip of gun to operating temperature.
2. Apply small amount of solder directly to the tip. (Figure 1)

FIGURE 1



3. Shake the tip slightly to remove excess solder.
4. Use a clean damp cloth to wipe off the soldering gun after use.

   (NOTE: This will aid in cleaning and tinning.)

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #7 — USE A FILE

A. Tools and materials

1. Safety glasses
2. File with handle
3. Vise
4. Stock to be filed

B. Procedure

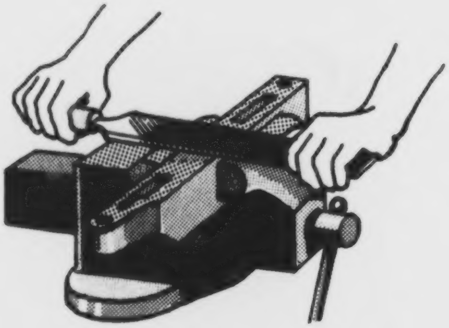
(CAUTION: Follow all shop safety procedures.)

1. Secure material being filed in a vise.

   (NOTE: Material being worked on should not extend very far above or beyond the jaws of the vise.)

2. Hold file firmly in both hands while filing.
3. Use long, even strokes with the file.
4. Apply pressure only on the forward stroke of the file. (Figure 1)

   FIGURE 1



(NOTE: Light pressure is usually sufficient when the right file is being used for the job.)

JOB SHEET #7

5. Lift file up slightly on the backward stroke to prevent damage to file.
6. Clean small particles of metal from file with a wire brush or file card.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #8 — USE THE OUTSIDE MICROMETER

A. Tools and materials

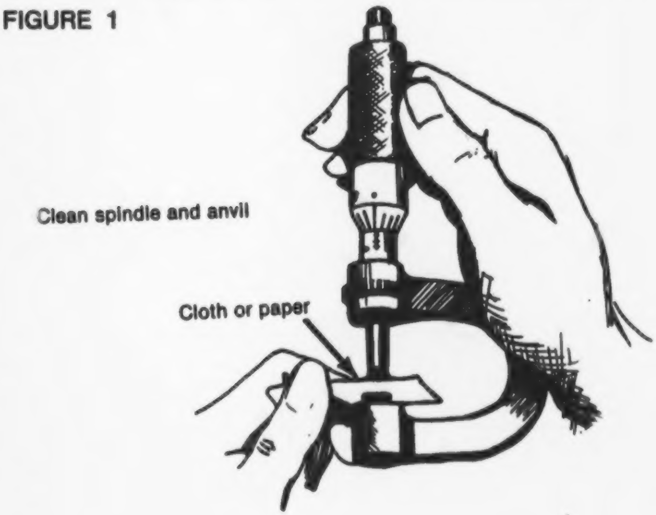
1. 0"-1.000" outside micrometer
2. 1.000"-2.000" outside micrometer
3. Lathe or vise
4. New fractional drill bits, assortment of 5
5. New letter size drill bits, assortment of 5
6. Pieces of metal such as cold rolled stock, machined parts, hardened dowels, assortment of 5

   (NOTE: All workpieces should be numbered or lettered for reference.)

B. Procedure

1. Select workpieces that are clean and free of burrs, nicks, or dents.
2. Select the proper size micrometer for the workpiece.
3. Clean the spindle and anvil of the micrometer. (Figure 1)

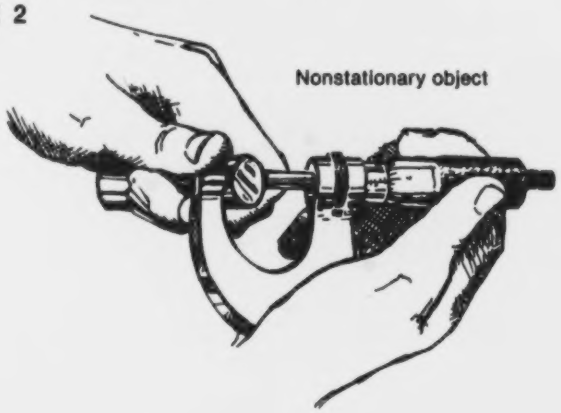
FIGURE 1



JOB SHEET #8

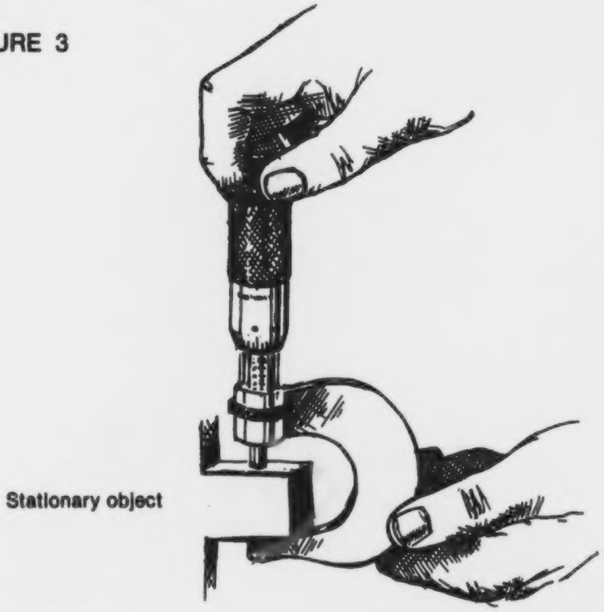
4. Check the micrometer at zero reference.
5. Hold the micrometer according to the type of workpiece.
    a. Hold the micrometer in the right hand and the workpiece in the left hand to measure a nonstationary object. (Figure 2)

FIGURE 2


Nonstationary object

    b. Hold the micrometer in both hands to measure a stationary object. (Figure 3)

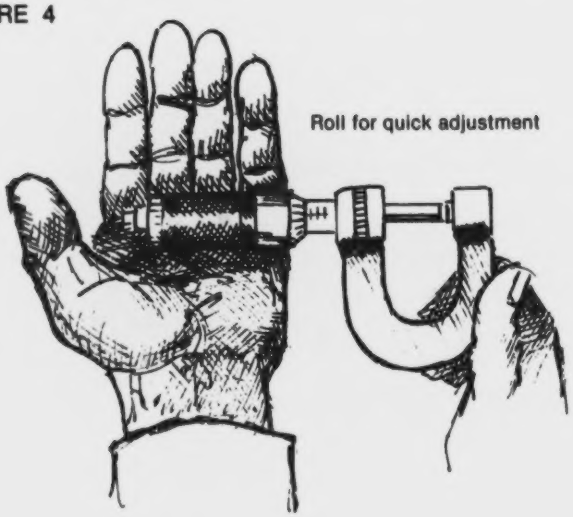
FIGURE 3


Stationary object

JOB SHEET #8

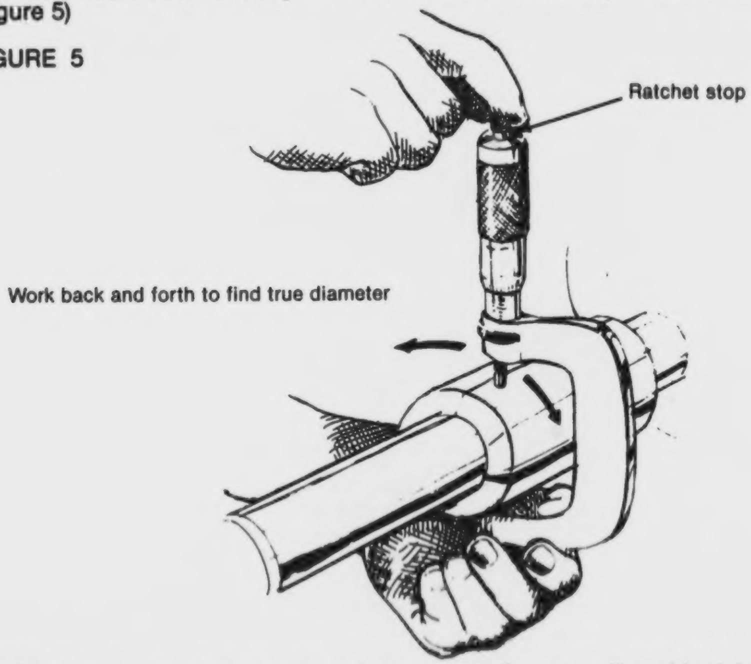
(NOTE: Roll micrometer along palm of hand or forearm for quick adjustment. See Figure 4.)

FIGURE 4


Roll for quick adjustment

6. Place the micrometer directly over the center of the workpiece to be measured. (Figure 5)

FIGURE 5


Ratchet stop
Work back and forth to find true diameter

(NOTE: Use the ratchet stop to ensure proper force on the object to be measured.)

JOB SHEET #8

7. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece.

8. Hold the anvil steady and move the spindle lightly over the workpiece to locate the true centerline. (Figure 5)

9. Use ratchet stop or light sense of feel to determine exact measurement.

10. Observe micrometer readings.

    (NOTE: Spindle lock can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.)

11. List the readings according to the letter or number on the workpiece.

12. Return the micrometer to its correct storage.

    (NOTE: The spindle and anvil of the micrometer should be left open when stored.)

13. Hand in the listed readings to the instructor for evaluation.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #9 — USE VERNIER CALIPER TO TAKE INSIDE, OUTSIDE, AND DEPTH MEASUREMENTS

A. Tools and materials

1. 6 or 8" universal vernier caliper
2. Pre-machined steel bar turned with four dimensions
3. Pre-machined steel, drilled and bored
4. Clean shop towel

B. Procedure for taking inside measurements

1. Grasp the vernier caliper in the right hand with vernier scale up.
2. Grasp part with left hand.
3. Use the thumb of the right hand to adjust caliper so inside portion of vernier will slide in bore, then open the jaw by sliding the slide toward your right until you feel a slight amount of pressure; take reading before removing from part. (Figures 1 and 2)

FIGURE 1

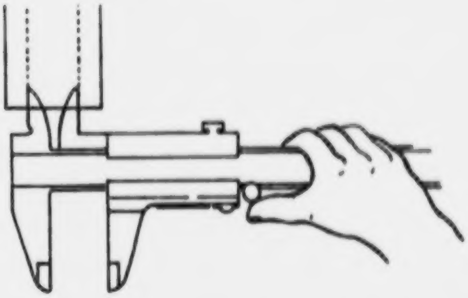
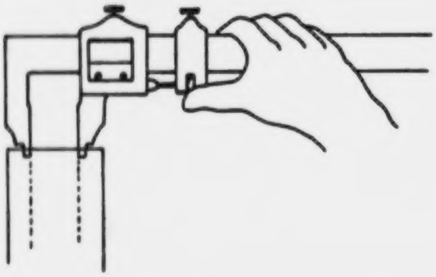
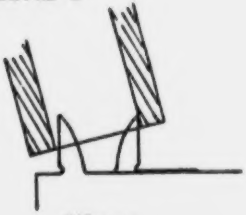


FIGURE 2



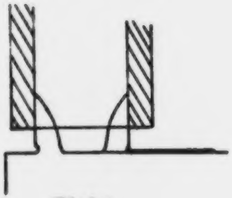
(NOTE: Be careful not to apply too much pressure, but keep the jaws squarely in the bore. See Figures 3 and 4 for example.)

FIGURE 3



Wrong

FIGURE 4

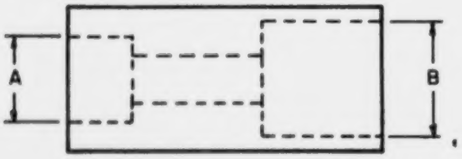


Right

JOB SHEET #9

4. Measure each of the inside bores and record your readings. (Figure 5)

FIGURE 5



______________________ A

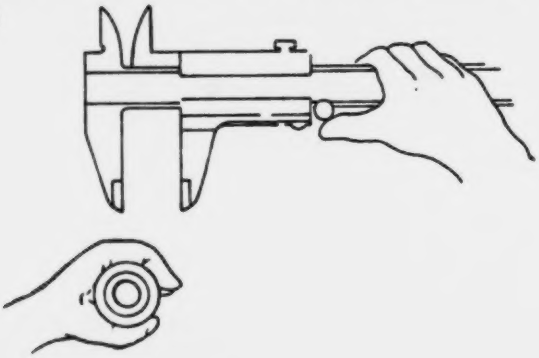
______________________ B

C. Procedure for taking outside measurements

1. Pick up the vernier caliper with your right hand so you are looking at the vernier scale.

2. Grasp the part to be measured in the left hand parallel to your body. (Figure 6)

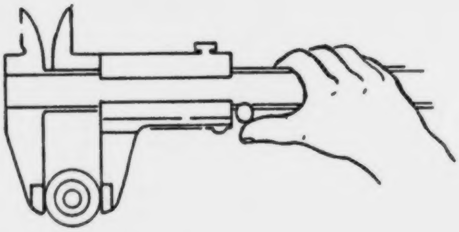
FIGURE 6



(NOTE: The thumb of the right hand can slide the sliding member along the beam of the vernier.)

3. Place the part between the two jaws close to beam, if possible; move the sliding member against the part by applying slight pressure with the thumb; take reading before removing part. (Figure 7)

FIGURE 7

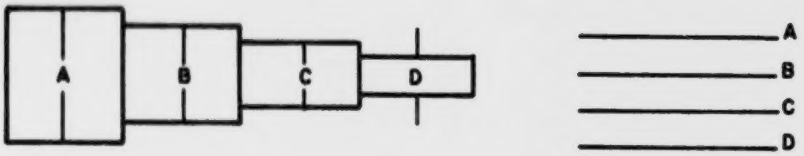


(CAUTION: Do not apply so much pressure that you spring the caliper.)

JOB SHEET #9

4. Start measuring at one end and work toward the other. Write each dimension in the spaces provided. (Figure 8)

FIGURE 8



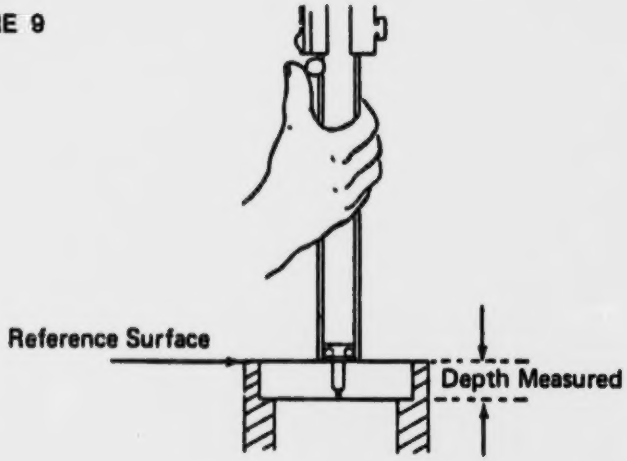
D. Procedure for taking depth measurements

1. Place the part to be measured on the bench with the deeper bore resting on the table.

2. Grasp the vernier caliper and place the base of the beam on the reference surface.

3. Using one hand to hold the caliper perpendicular to the reference surface, use the free hand to move the slide down until you feel the blade make contact with the lip or surface to be measured; take measurement before removing part. (Figure 9)

FIGURE 9



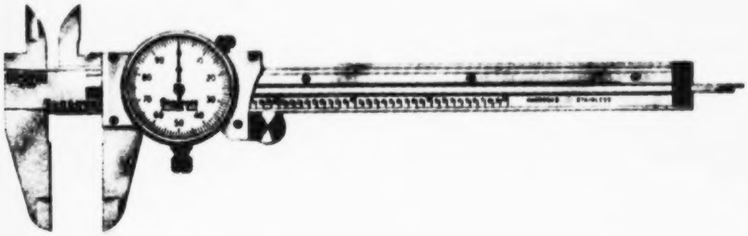
4. Record your reading ______________.

JOB SHEET #9

5. Turn part end for end and measure the depth of the bore on the other end; record your reading ____________.

   (NOTE: Some vernier calipers have a dial. The application and use is the same as the universal vernier caliper, but the dial makes it easier and faster to read. [Figure 10])

   FIGURE 10



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BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #10 — USE THE DEPTH MICROMETER

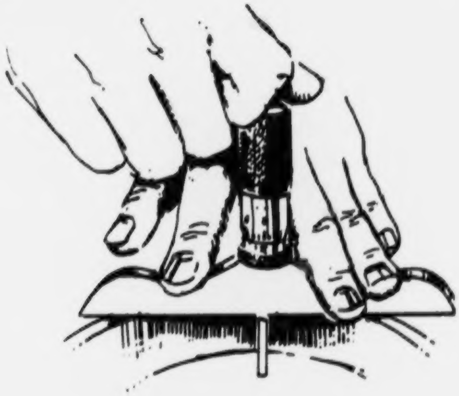
A. Tools and materials

1. A depth micrometer set which includes extension rods
2. Assortment of machined workpieces with grooves, slots, or shoulders
3. Clean shop towel

B. Procedure

1. Select workpieces that are clean and free of burrs, nicks, or dents.
2. Clean the depth micrometer base and measuring rod with a clean cloth.
3. Select the correct extension rod.
4. Install the extension rod.
5. Check zero reference.
6. Place the base of the depth micrometer firmly against the surface of the workpiece. (Figure 1)

FIGURE 1



JOB SHEET #10

7. Turn the thimble of the depth micrometer until the measuring rod lightly contacts the bottom of the slot or groove.

8. Read the micrometer measurement.

   (NOTE: The thimble and sleeve are numbered in reverse order from those of a standard micrometer. Read the measurement on the micrometer covered by the thimble.)

9. Record your reading ______________.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #11 — USE A DIAL INDICATOR

A. Tools and materials

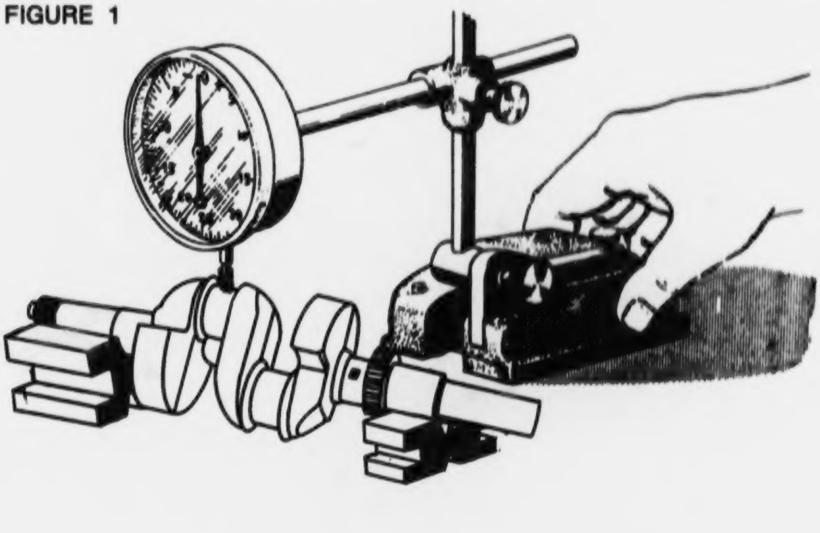
   1. Dial indicator
   2. Dial indicator holder
   3. Magnetic base
   4. V blocks — 2
   5. Appropriate assortment of machined parts

   (NOTE: All workpieces should be numbered or lettered for reference.)

B. Procedure

   1. Select workpieces that are clean and free of burrs, nicks, or dents.
   2. Attach dial indicator to holder.
   3. Secure holder to work surface.
   4. Mount workpiece according to type of measurement to be made. (Figure 1)

FIGURE 1



JOB SHEET #11

5. Position holder so that dial indicator plunger contacts workpiece.

6. Adjust holder so that plunger is depressed two revolutions of pointer and tighten holder.

7. Rotate bezel until the zero marking is in line with pointer.

8. Measure workpiece for taper, concentricity, and run-out.

9. List readings according to the letter or number on the workpiece.

10. Record your reading ______________.

11. Disassemble dial indicator and holder and return to the correct storage.

12. Hand in the listed readings to the instructor for evaluation.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #12 — USE A CYLINDER BORE GAUGE

A. Tools and materials

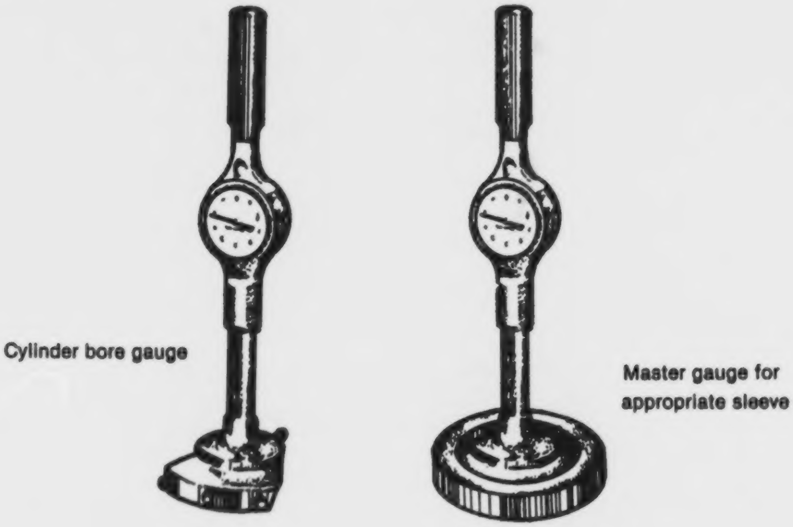
1. Cylinder bore gauge
2. Master gauge for appropriate cylinder
3. Cylinder sleeve
4. Clean shop towels

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clean all tools and cylinder sleeve.
2. Look in appropriate manual and record specification ________________.
3. Place cylinder bore gauge into the master gauge. (Figure 1)

FIGURE 1

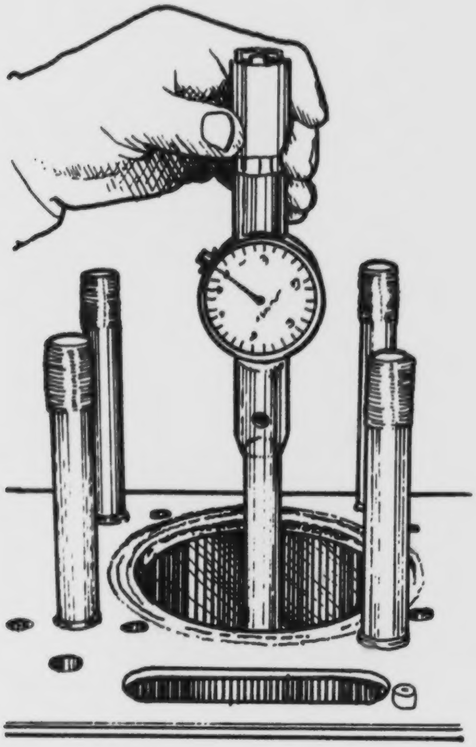

Cylinder bore gauge
Master gauge for appropriate sleeve

4. Adjust face of dial indicator to zero.

JOB SHEET #12

5. Remove bore gauge from master gauge.
6. Insert the bore gauge into the cylinder bore. (Figure 2)

FIGURE 2



7. Record your measurement ______________.

   (NOTE: If the pointer moves to the left of the zero mark, the cylinder bore's diameter is larger than maximum allowable wear. If the pointer moves to the right of the zero mark, the diameter is less than the allowable wear.)

8. Repeat the measurement at each point recommended in the service manual.
9. Place tools and equipment back in storage area.
10. Have instructor initial here ______________.

BASIC SHOP TOOLS
UNIT II-A

JOB SHEET #13 — USE THE TELESCOPING GAUGE

A. Tools and materials

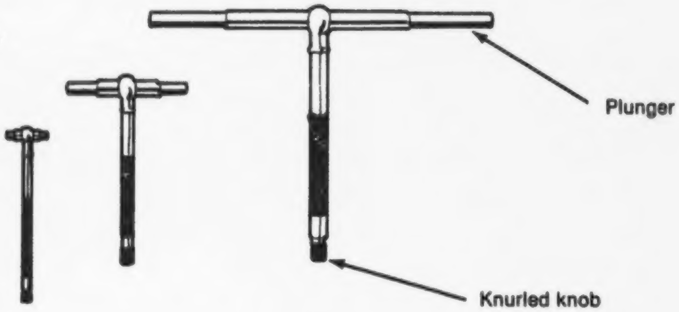
1. Set of telescoping gauges
2. Outside micrometer
3. Cylinder block with camshaft removed
4. Clean shop towels

B. Procedures

(CAUTION: Follow all shop safety procedures.)

1. Measure the hole size and select the proper gauge from the telescoping gauges. (Figure 1)

FIGURE 1

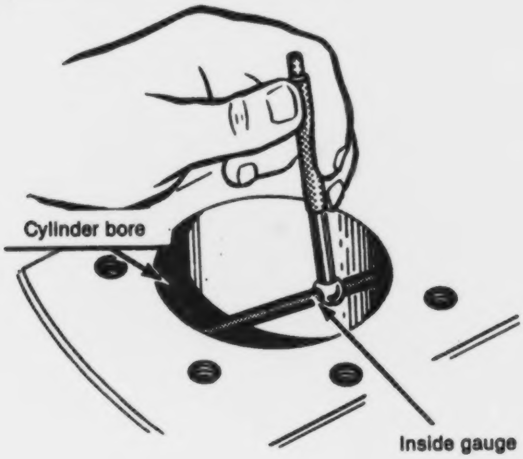


2. Clean the gauge and the hole.
3. Depress the plungers until slightly smaller than hole diameter and clamp in this position.

JOB SHEET #13

4. Insert gauge into the hole, and with the handle tilted upwards slightly, release the plungers. (Figure 2)

FIGURE 2



5. Lightly "snug up" the knurled knob.

6. Hold the bottom leg of the telescoping gauge in position with one hand.

7. Move the handle downwards through the center while slightly moving the top leg from side to side.

8. Tighten the plungers in position.

9. Recheck the "feel" on the gauge by testing it in the hole again.

10. Check the gauge size with outside micrometers, maintaining the same "feel" as in the hole.

11. Record your measurements ______________.

12. Place tools and equipment back in storage area.

13. Have instructor initial here ______________.

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #1 — SHARPEN A TWIST DRILL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Put on safety glasses.	______	______
3. Held drill bit at proper angle.	______	______
4. Rotated bit in correct manner.	______	______
5. Ground both lips the same.	______	______
6. Watched that tip didn't get too hot.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Drill bit is sharp.	4	3	2	1
Both lips have same angle.	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #2 — DRILL HOLES WITH A DRILL PRESS

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Put on safety glasses.	______	______
3. Used all safety precautions.	______	______
4. Measured material to find center.	______	______
5. Used hammer and center punch correctly.	______	______
6. Secured material onto drill press.	______	______
7. Selected correct speed for material.	______	______
8. Checked for alignment.	______	______
9. Used cutting oil on drill bit.	______	______
10. Operated equipment correctly.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Hole is straight.	4	3	2	1
Hole is smooth.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #3 — SHARPEN A COLD CHISEL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Put on safety glasses.	______	______
3. Used all safety precautions.	______	______
4. Checked grinder and tool rest adjustment.	______	______
5. Held chisel at correct angle.	______	______
6. Moved chisel across grinding wheel.	______	______
7. Kept tip cool.	______	______
8. Ground both sides equally.	______	______
9. Reshaped head correctly.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Chisel is sharpened and reshaped appropriately.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #4 — DRESS A GRINDING WHEEL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.		
2. Put on safety glasses.		
3. Selected proper dressing tool.		
4. Used correct procedure.		
5. Readjusted tool rest.		
6. Used all safety precautions.		
7. Checked in/put away tools and materials.		
8. Cleaned the work area.		
9. Used proper tools correctly.		
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)		
11. Practiced safety rules throughout procedure.		
12. Provided satisfactory responses to questions asked.		

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Grinding wheel edges are square with side.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #5 — CHECK TORQUE WRENCH FOR ACCURACY

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Secured torque wrench.	______	______
4. Zeroed indicator.	______	______
5. Placed weight on handle.	______	______
6. Calculated answer.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Torque wrench accuracy				

EVALUATOR'S COMMENTS:

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #6 — TIN A SOLDERING GUN

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Operated equipment properly.	______	______
4. Applied solder correctly.	______	______
5. Cleaned excess solder off gun.	______	______
6. Cleaned equipment.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Appearance of tinned tip				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #7 — USE A FILE

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Secured material correctly.	______	______
4. Held file correctly.	______	______
5. Used correct stroke.	______	______
6. Used right amount of pressure.	______	______
7. Held file correctly on backward stroke.	______	______
8. Cleaned file correctly.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Material was filed correctly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #8 — USE THE OUTSIDE MICROMETER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Selected proper size micrometer.	______	______
4. Cleaned the micrometer.	______	______
5. Checked the micrometer for zero.	______	______
6. Held micrometer correctly.	______	______
7. Used micrometer correctly.	______	______
8. Read micrometer correctly.	______	______
9. Wrote down micrometer reading correctly.	______	______
10. Replaced micrometer in storage case.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #8 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Outside micrometer measurement is correct.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #9 — USE VERNIER CALIPER TO TAKE INSIDE, OUTSIDE, AND DEPTH MEASUREMENTS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Held caliper correctly.	______	______
4. Measured inside bore.	______	______
5. Measured outside diameter.	______	______
6. Measured bore depth.	______	______
7. Took caliper readings.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #9 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Inside caliper measurement is correct.	4	3	2	1
Outside caliper measurement is correct.	4	3	2	1
Depth caliper measurement is correct.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #10 — USE THE DEPTH MICROMETER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Cleaned material being measured.	______	______
4. Selected correct extension rod.	______	______
5. Zeroed micrometer.	______	______
6. Measured depth.	______	______
7. Recorded reading of micrometer.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #10 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Depth micrometer measurements are correct.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #11 — USE A DIAL INDICATOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Attached indicator correctly.	______	______
4. Zeroed dial indicator.	______	______
5. Measured workpiece correctly.	______	______
6. Recorded reading.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #11 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Dial indicator measurements are correct.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #12 — USE A CYLINDER BORE GAUGE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Cleaned tools before measuring.	______	______
4. Used master gauge correctly.	______	______
5. Zeroed dial indicator.	______	______
6. Measured cylinder bore.	______	______
7. Recorded readings.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #12 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Cylinder bore gauge measurements are correct.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

PRACTICAL TEST
JOB SHEET #13 — USE THE TELESCOPING GAUGE

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Selected proper telescoping gauge.	______	______
4. Used telescoping gauge correctly.	______	______
5. Used outside micrometer correctly.	______	______
6. Recorded measurements.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #13 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Measurements with telescoping gauge are correct.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

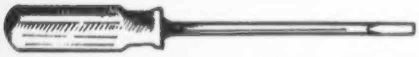
(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BASIC SHOP TOOLS
UNIT II-A

NAME ______________________ SCORE ____________________

TEST

1. Identify the basic shop tools.



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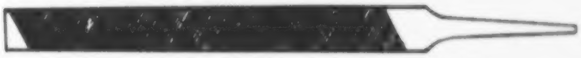
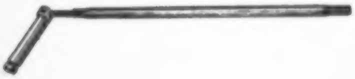
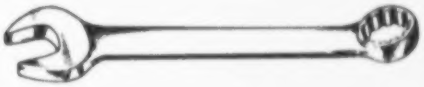


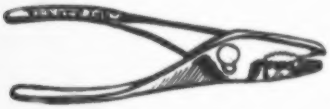
b. ______________________



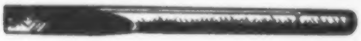
c. ______________________



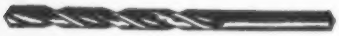
d. ______________________



e. ______________________



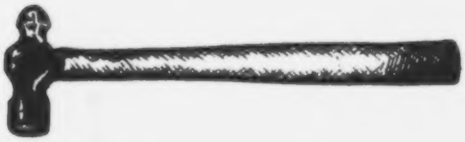
f. ______________________



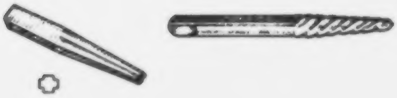
g. ______________________

h. ______________________

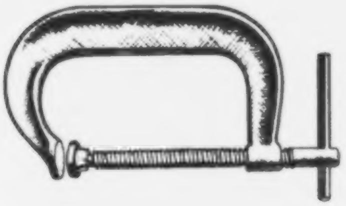
TEST



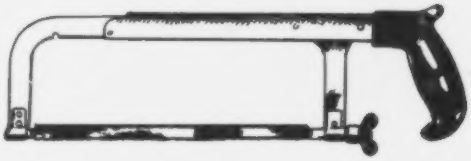
i. ______________________________



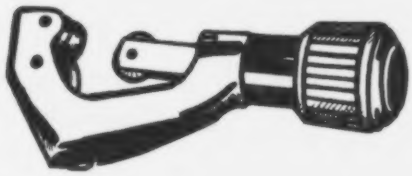
j. ______________________________



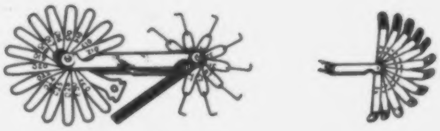
k. ______________________________



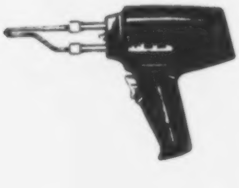
l. ______________________________



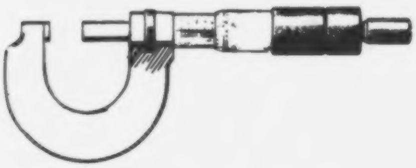
m. ______________________________



n. ______________________________

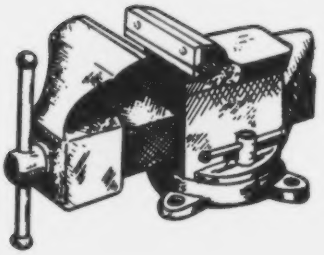


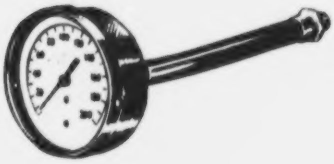
o. ______________________________



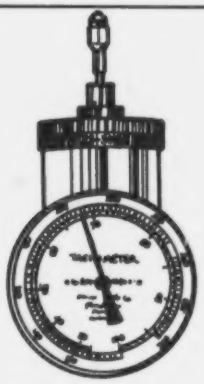
p. ______________________________

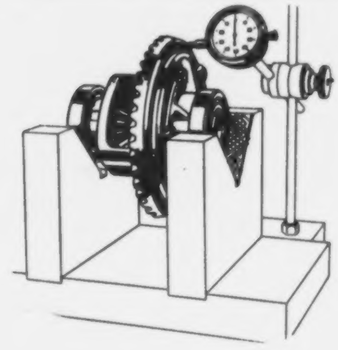
TEST



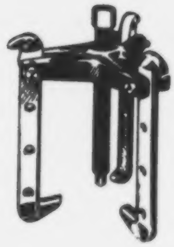


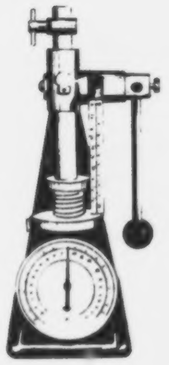
q. ______________________________ r. ______________________________





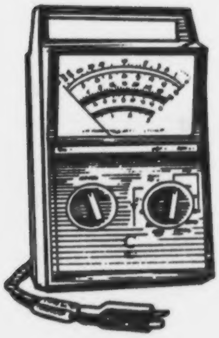
s. ______________________________ t. ______________________________





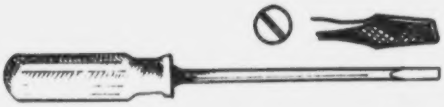
u. ______________________________ v. ______________________________

TEST

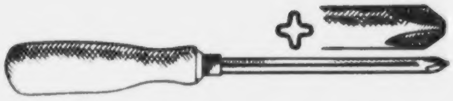


w. ______________________________

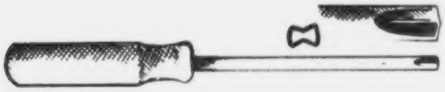
2. Identify types of screwdrivers.



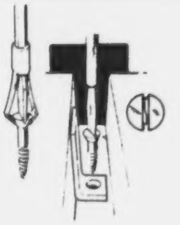
a. ______________________________



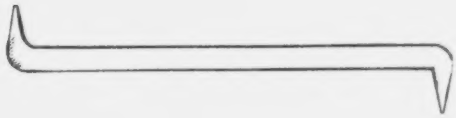
b. ______________________________



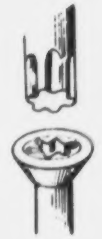
c. ______________________________



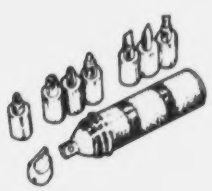
d. ______________________________



e. ____________________



f. ____________________



g. ____________________

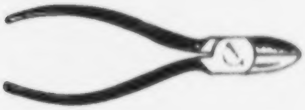
TEST

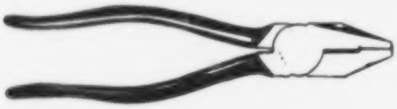
3. Name two types of hammers.

a. ______________________________

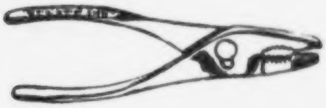
b. ______________________________

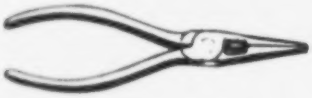
4. Identify the types of pliers.



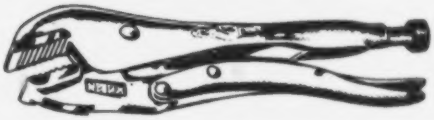


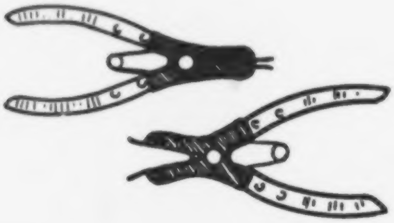
a. ____________________ b. ____________________



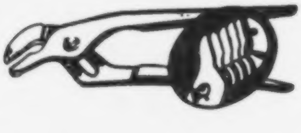


c. ____________________ d. ____________________





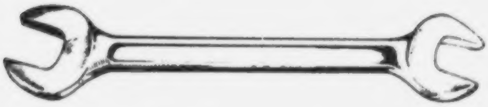
e. ____________________ f. ____________________



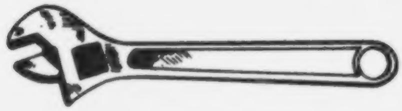
g. ____________________

TEST

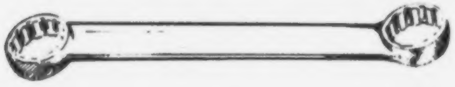
5. Identify the types of wrenches.



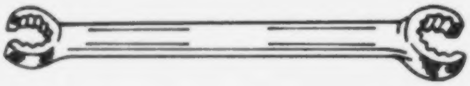
a. ______________________________



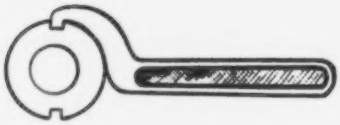
b. ______________________________



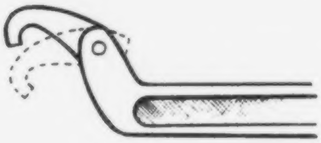
c. ______________________________



d. ______________________________



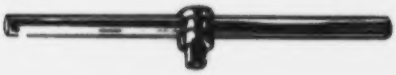
e. ______________________________



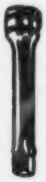
f. ______________________________

TEST

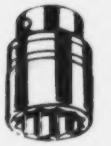
g.



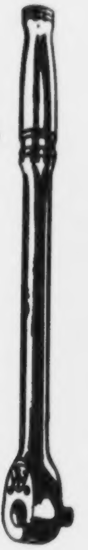
h.



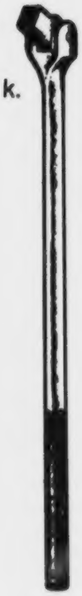
i.



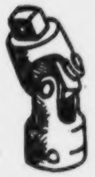
j.



k.



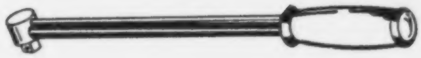
l.

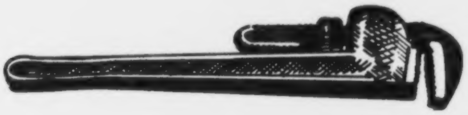


g. ______________________________ h. ______________________________

i. ______________________________ j. ______________________________

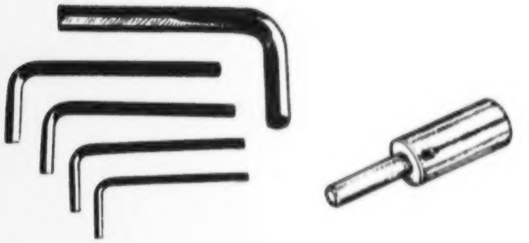
k. ______________________________ l. ______________________________

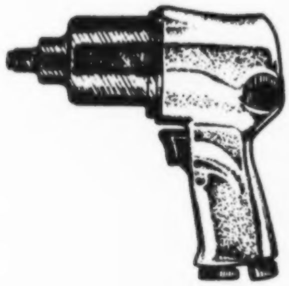




m. ______________________________ n. ______________________________

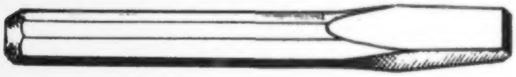
TEST

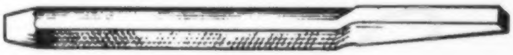




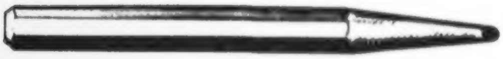
o. ______________________________ p. ______________________________

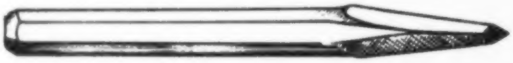
6. Identify the types of cold chisels.





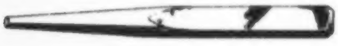
a. ______________________________ b. ______________________________





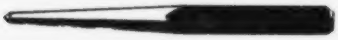
c. ______________________________ d. ______________________________

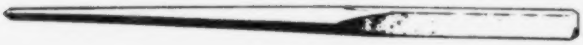
7. Identify the types of punches.



a. ______________________________ b. ______________________________

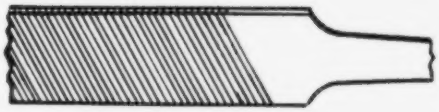
TEST

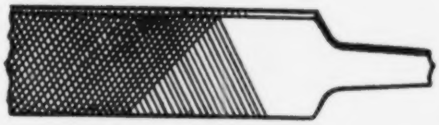




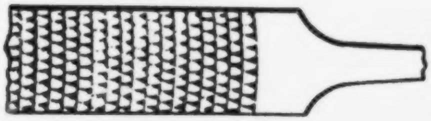
c. ____________________ d. ____________________

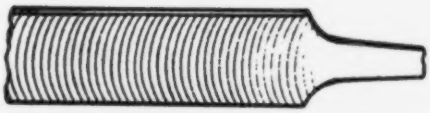
8. Identify types of file teeth.





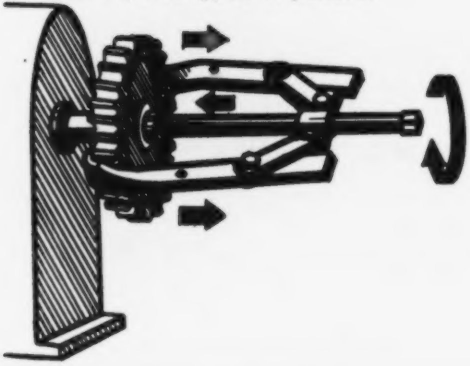
a. ____________________ b. ____________________

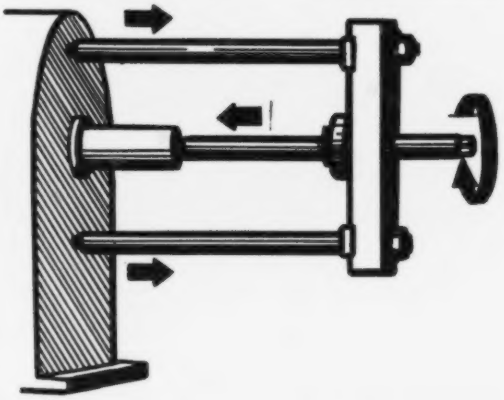




c. ____________________ d. ____________________

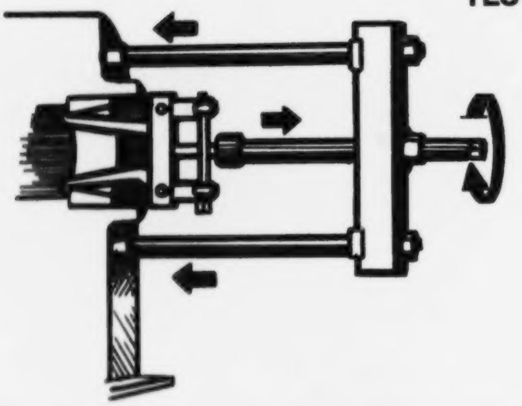
9. Identify five types of pullers.



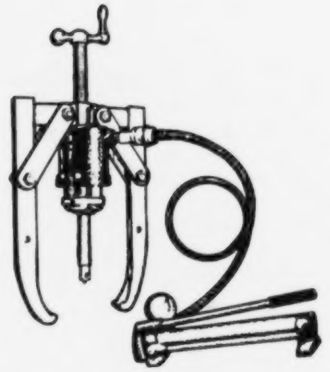


a. ____________________ b. ____________________

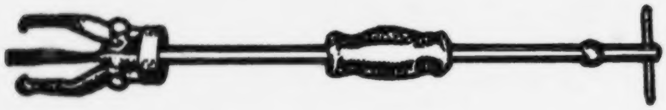
TEST



c. ____________________________________

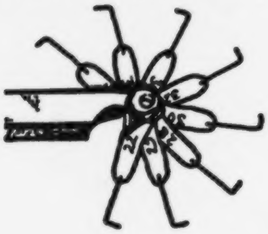


d. ____________________________________

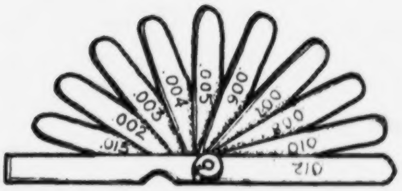


e. ____________________________________

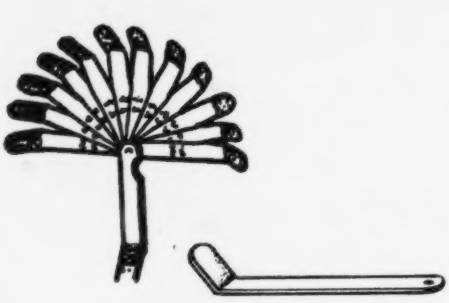
10. Identify the following types of feeler gauges.



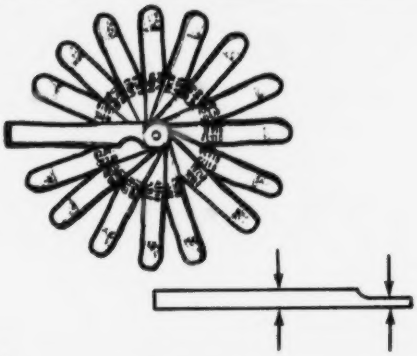
a. ____________________________________


.015
.002
.003
.004
.005
.006
.007
.008
.010
.012

b. ____________________________________



c. ____________________________________



d. ____________________________________

TEST

11. Match the three types of taps on the right with their correct functions.

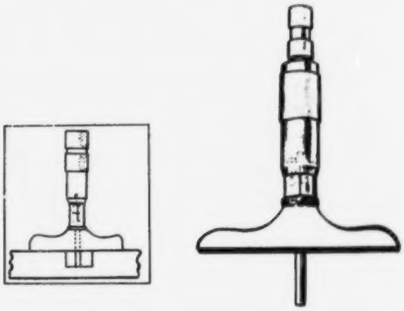
_____a. Used last to cut the thread to the bottom of the hole (if necessary)

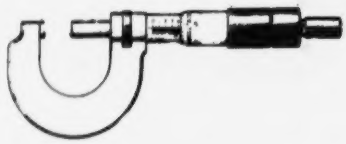
_____b. Used to start the thread

_____c. Used after taper tap has cut the threads as far as possible

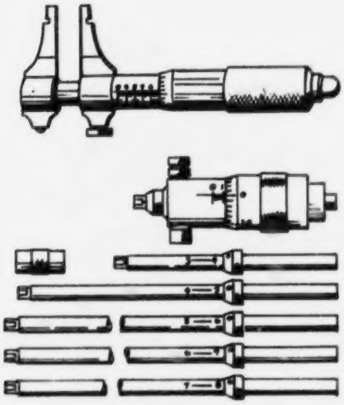
1. Bottoming
2. Plug
3. Taper

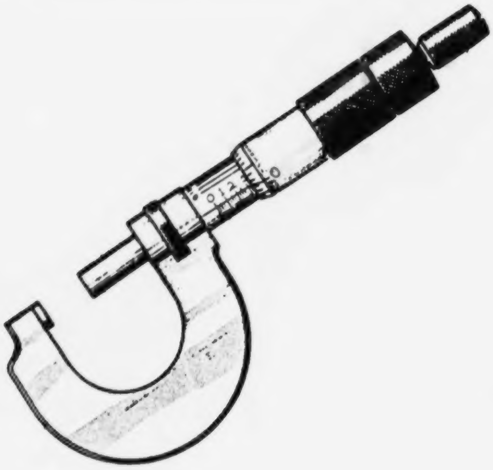
12. Identify the following five types of micrometers.





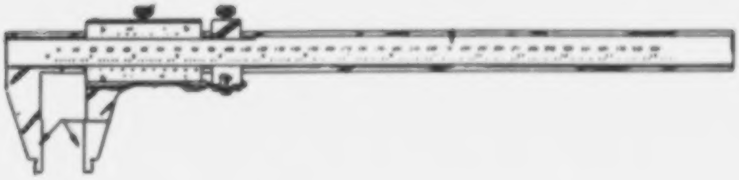
a. ______________________________ b. ______________________________





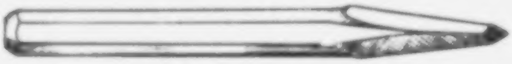
c. ______________________________ d. ______________________________

TEST

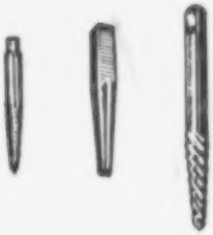


e. ______________________________

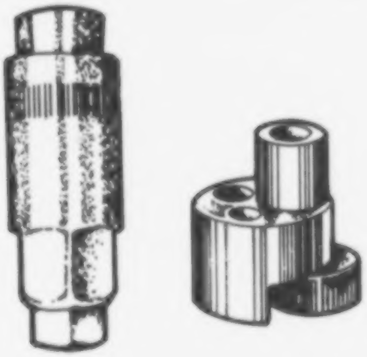
13. Identify three ways to extract a screw.



a. ______________________________



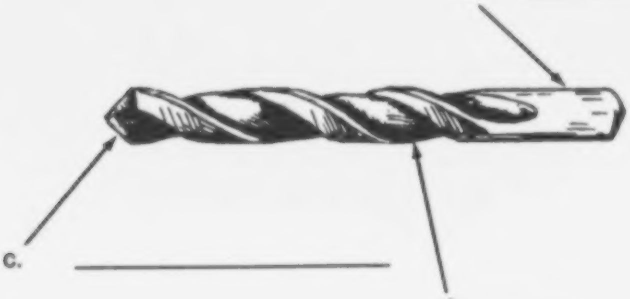
b. ______________________________



c. ______________________________

TEST

14. Identify three principal parts of a twist drill.



a. ______________________

b. ______________________

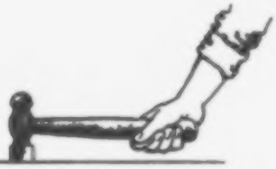
c. ______________________

15. Name two shop tools used for measuring shaft speed.

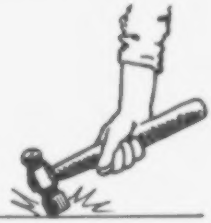
a. ____

b. ____

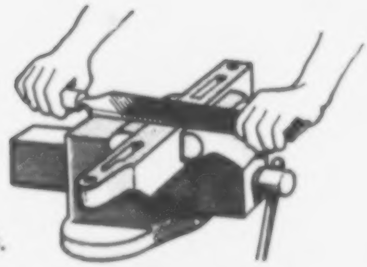
16. Distinguish between correct and incorrect methods of using and maintaining basic shop tools by placing an "X" beside the illustration of correct methods.



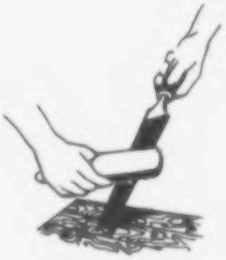
_____a.



_____b.

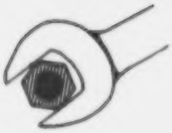


_____c.

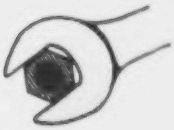


_____d.

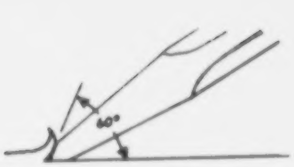
TEST



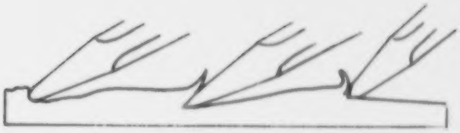
______e.



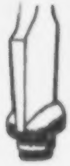
______f.



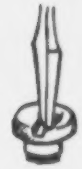
______g.



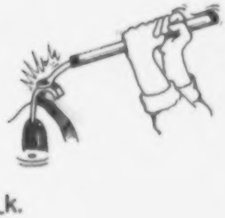
______h.



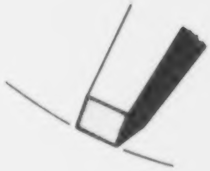
______i.



______j.

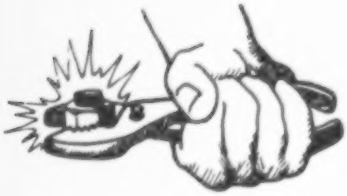


______k.

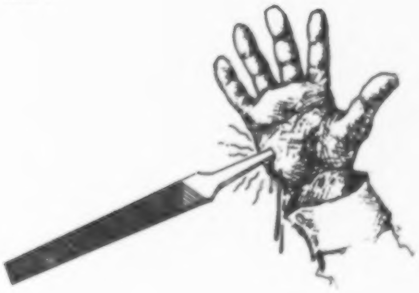


______l.

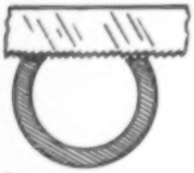
TEST



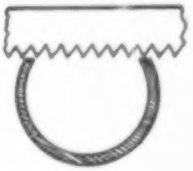
______m.



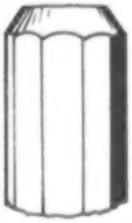
______n.



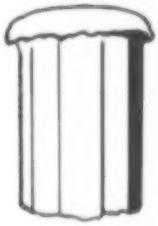
______o.



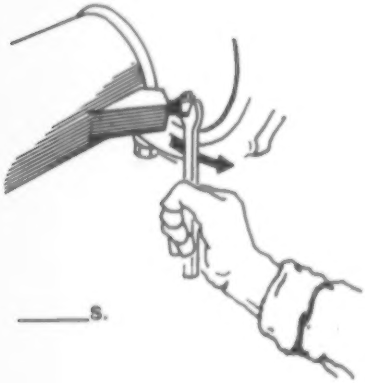
______p.



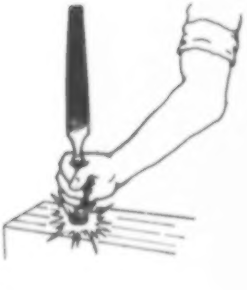
______q.



______r.

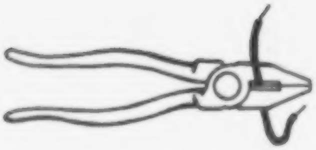


______s.

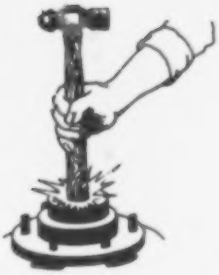


______t.

TEST



_____u.



_____v.

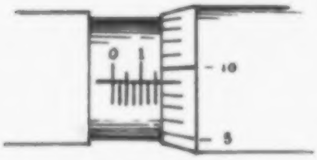
17. Name three precautions for correct use of the hacksaw.

a. ____________________

b. ____________________

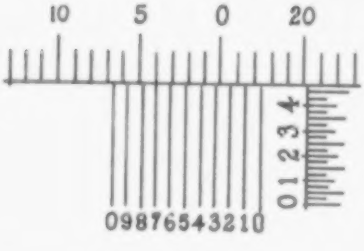
c. ____________________

18. Read the micrometer setting.



Answer ____________

19. Read the vernier micrometer setting.


10
5
0
20
0 1 2 3 4
0 9 8 7 6 5 4 3 2 1 0

Answer ____________

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

    a. Sharpen a twist drill. (Job Sheet #1)

    b. Drill holes with a drill press. (Job Sheet #2)

    c. Sharpen a cold chisel. (Job Sheet #3)

    d. Dress a grinding wheel. (Job Sheet #4)

    e. Check a torque wrench for accuracy. (Job Sheet #5)

    f. Tin a soldering gun. (Job Sheet #6)

    g. Use a file. (Job Sheet #7)

    h. Use the outside micrometer. (Job Sheet #8)

    i. Use the vernier caliper to take inside, outside, and depth measurements. (Job Sheet #9)

    j. Use the depth micrometer. (Job Sheet #10)

    k. Use a dial indicator. (Job Sheet #11)

    l. Use a cylinder bore gauge. (Job Sheet #12)

    m. Use the telescoping gauge. (Job Sheet #13)

BASIC SHOP TOOLS
UNIT II-A

ANSWERS TO TEST

1. a. Common screwdriver
   b. Flat file
   c. Magnetic pick-up tool
   d. Combination box and open-end wrench
   e. Slip joint pliers
   f. Flat cold chisel
   g. Twist drill
   h. Center punch
   i. Ball peen hammer
   j. Screw extractor
   k. "C" clamp
   l. Hacksaw
   m. Tubing cutter
   n. Feeler gauge
   o. Soldering gun
   p. Outside micrometer
   q. Vise
   r. Pressure gauge
   s. Tachometer
   t. Dial indicator
   u. External puller
   v. Spring tester
   w. Multimeter

2. a. Common
   b. Phillips head
   c. Clutch head
   d. Starting
   e. Offset
   f. Torx
   g. Impact screwdriver

3. a. Ball peen
   b. Soft face

4. a. Diagonal cutters
   b. Side cutters
   c. Slip joint
   d. Needle nose
   e. Lock grip
   f. Snap ring
   g. Channel lock

ANSWERS TO TEST

5. a. Open end
   b. Adjustable
   c. Box
   d. Tubing
   e. Hook spanner
   f. Adjustable hook spanner
   g. Sliding "T" handle
   h. Extension
   i. Socket
   j. Ratchet handle
   k. Flex handle
   l. Universal joint
   m. Torque
   n. Pipe
   o. Allen
   p. Air impact wrench

6. a. Flat
   b. Cape
   c. Round nose
   d. Diamond point

7. a. Starting
   b. Pin
   c. Center
   d. Aligning

8. a. Single cut
   b. Double cut
   c. Rasp cut
   d. Curved tooth

9. a. External
   b. Press
   c. Internal
   d. Hydraulic puller
   e. Slide hammer

10. a. Wire
    b. Standard
    c. Bent
    d. Stepped

11. a. 1
    b. 3
    c. 2

ANSWERS TO TEST

12. a. Depth
    b. Outside
    c. Inside
    d. Vernier
    e. Calipers

13. a. Diamond point chisel
    b. Screw extractor
    c. Stud puller

14. a. Shank
    b. Flute
    c. Cutting edge

15. a. Tachometer
    b. Timing light (Stroboscope)

16. a, c, d, f, g, i, l, o, q, s, t, u

17. Any three of the following:
    a. Teeth must point away from handle
    b. Blade must be tightly stretched
    c. Select blade with correct number of teeth per inch for material being cut
    d. Use sufficient pressure on the forward stroke
    e. Use full length of blade on each stroke

18. 0.159

19. 0.4697

20. Performance skills evaluated to the satisfaction of the instructor

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify test equipment and service tools and match them to the correct functions. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to test equipment and service tools with the correct definitions.
2. Distinguish between test equipment and service tools.
3. Identify types of test equipment.
4. Identify types of service tools.
5. Match test equipment with the correct functions.
6. Match service tools with the correct functions.
7. Demonstrate the ability to:
    a. Check compression with a compression gauge. (Job Sheet #1)
    b. Check bearing clearance with Plastigage®. (Job Sheet #2)
    c. Test radiator with radiator tester. (Job Sheet #3)
    d. Test a thermostat. (Job Sheet #4)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information sheet.

E. Discuss information sheet.

F. Provide students with job sheets.

G. Discuss and demonstrate the procedures outlined in the job sheets.

H. Integrate the following activities throughout the teaching of this unit:

   1. Demonstrate the use of equipment.

   2. Demonstrate the use of service tools.

   3. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

I. Give test.

J. Evaluate test.

K. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Dagel, John F. *Diesel Engine Repairs.* New York: John Wiley and Sons, Inc., 1982.

B. *Detroit Diesel Engines: Service Manual.* Detroit, MI, 1985.

C. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

D. Schulz, Erich J. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

1. *Educational Materials*
John Deere Distribution Service Center
Service Training, Dept. 333
1400 3rd Avenue
Moline, IL 61265
(309) 757-5903

2. *Caterpillar Service Training Materials Catalog*
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602

3. *Mack Service Training Aids*
Educational Communications, Inc.
Dept. M
761 Fifth Avenue
King of Prussia, PA 19406

(NOTE: Check with the local distributor in your community for more information.)

B. **Filmstrips**

1. *How To Use Cooling Systems Diagnostic Tools — Pressuring Pump*
Video Tape 96, 13 minutes
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602

2. *Valve Service: Seating and Assembly Procedure*
1 filmstrip (33 frames)
Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92628-0798

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

INFORMATION SHEET

I. **Terms and definitions**

A. Diagnose — To recognize by signs or symptoms

B. Ream — To enlarge or dress out a hole or bore

C. Thermocouple — Two dissimilar wires joined at one end and used to measure temperature differences

D. Troubleshooting — The act of analyzing, testing, and measuring the engine to remedy the cause of trouble

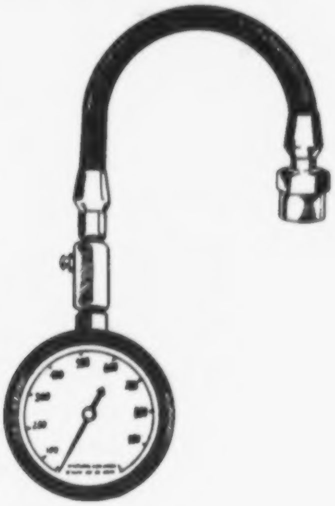
II. **Function of test equipment and service tools**

A. Test equipment — To diagnose the engine

B. Service tools — To repair the engine

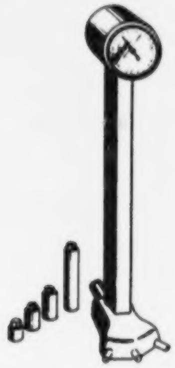
III. **Test equipment**

A. Cylinder compression gauge

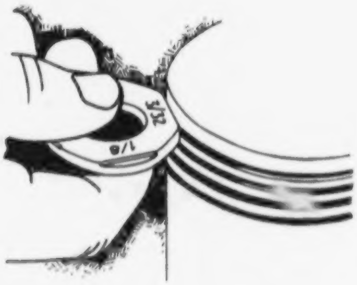


INFORMATION SHEET

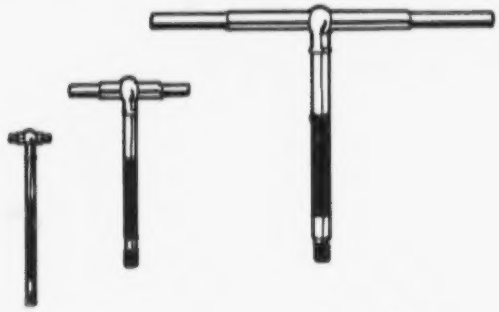
B. Cylinder bore gauge



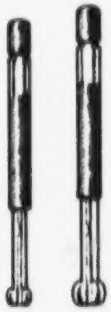
C. Ring groove wear gauge



D. Piston pin bore gauges



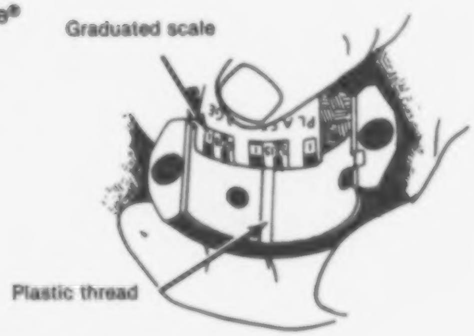
Telescoping gauges



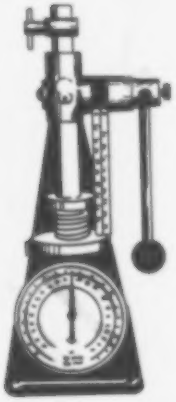
Small bore gauges

INFORMATION SHEET

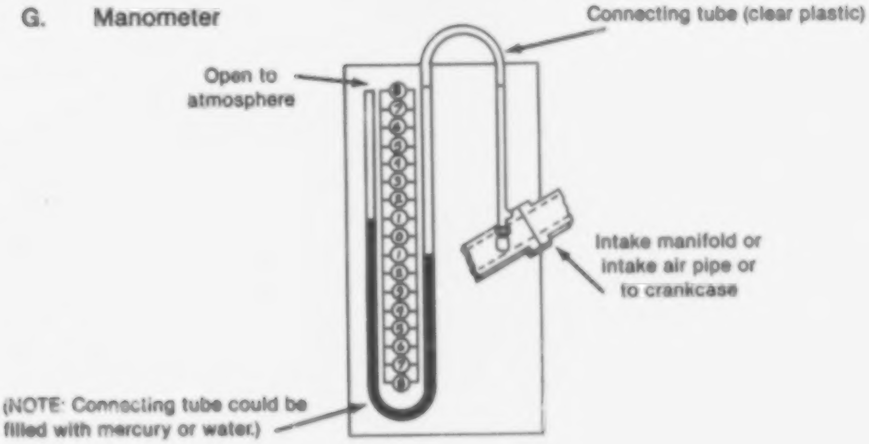
E. Plastigage®


Graduated scale
Plastic thread

F. Valve spring tester

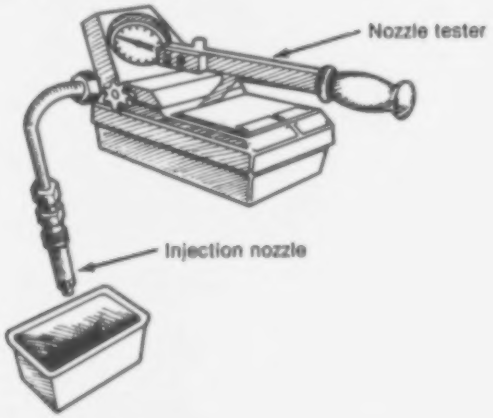


G. Manometer

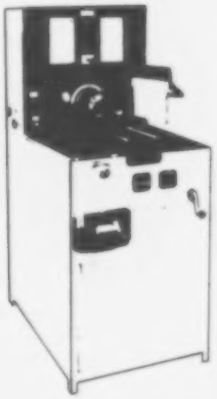

Connecting tube (clear plastic)
Open to atmosphere
Intake manifold or intake air pipe or to crankcase
(NOTE: Connecting tube could be filled with mercury or water.)

INFORMATION SHEET

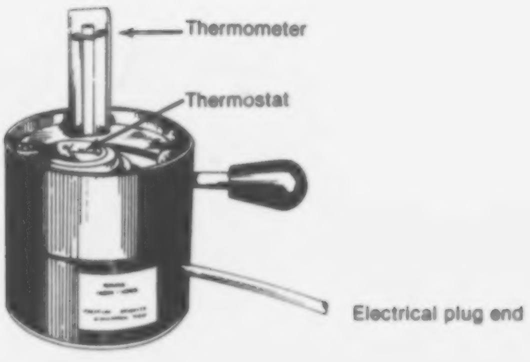
H. Injection nozzle tester (diesel)


Nozzle tester
Injection nozzle

I. Injection pump test stand

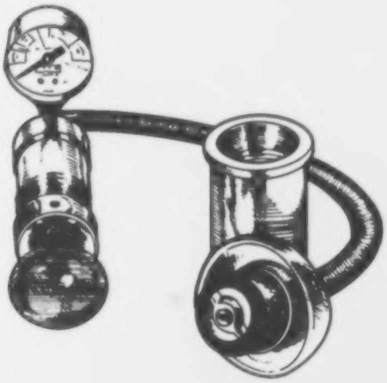


J. Thermostat tester

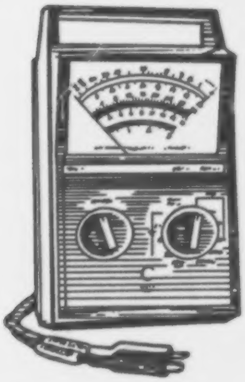

Thermometer
Thermostat
Electrical plug end

INFORMATION SHEET

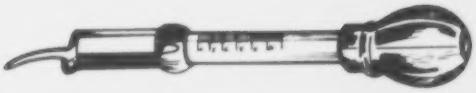
K. Radiator and cap tester



L. Multimeter

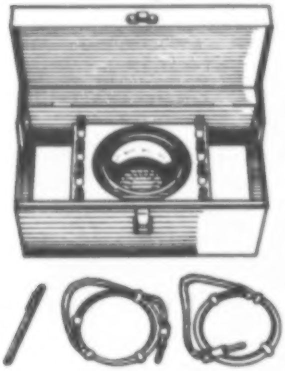


M. Battery hydrometer



INFORMATION SHEET

N. Pyrometer

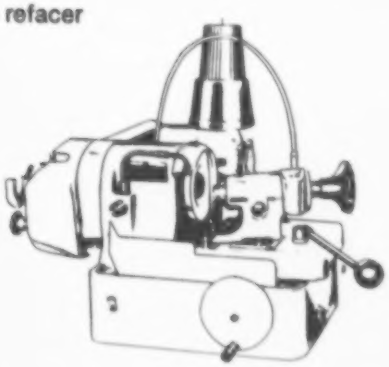


O. Dynamometer

(Courtesy of AW Dynamometer, Inc.)

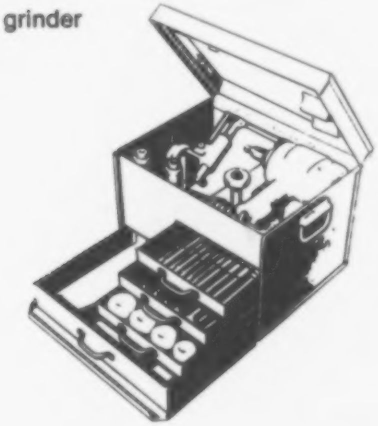
IV. Service tools

A. Valve refacer

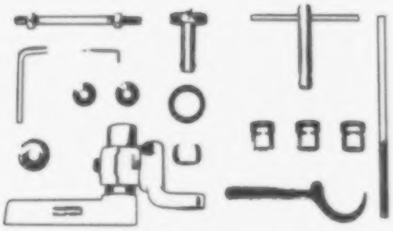


INFORMATION SHEET

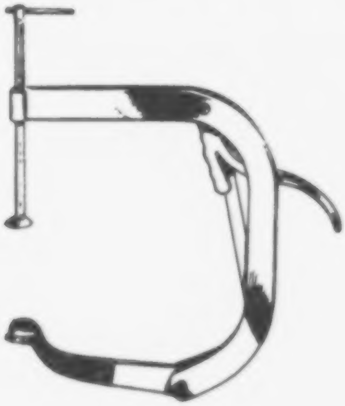
B. Valve seat grinder



C. Valve guide reamer

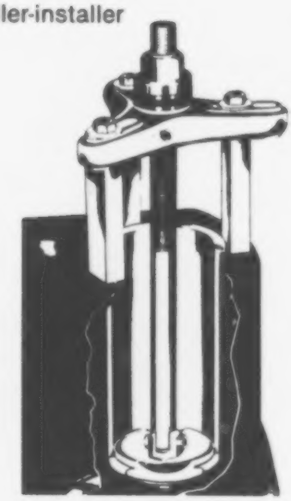


D. Valve spring compressor

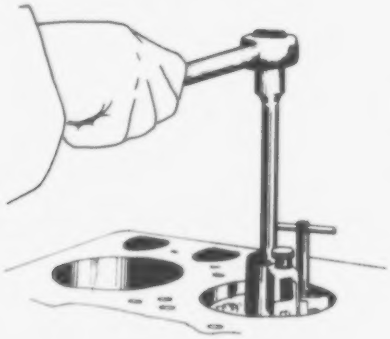


INFORMATION SHEET

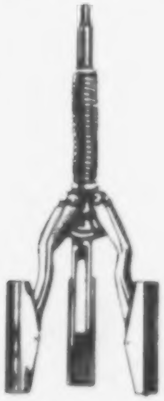
E. Cylinder liner puller-installer



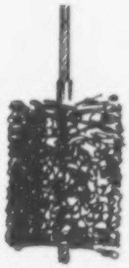
F. Cylinder ridge reamer



G. Cylinder deglazer



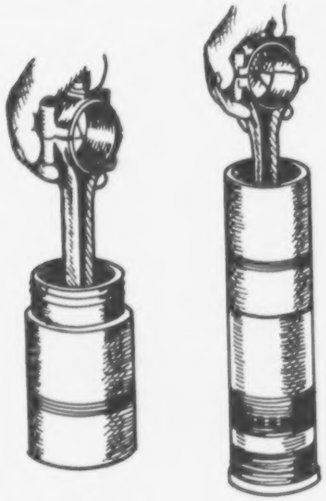
Stone



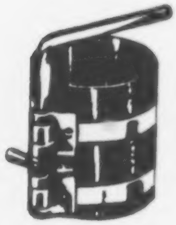
Bead

INFORMATION SHEET

H. Piston ring compressor

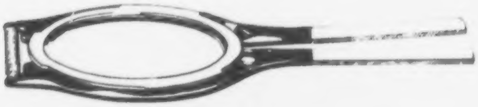


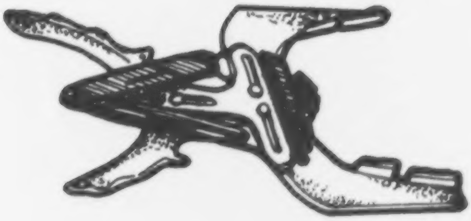
Tapered sleeve



Band

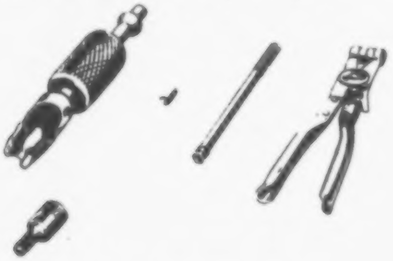
I. Piston ring expander



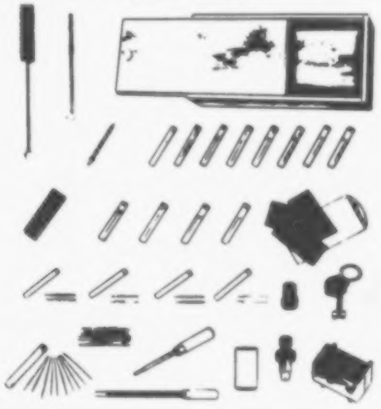


INFORMATION SHEET

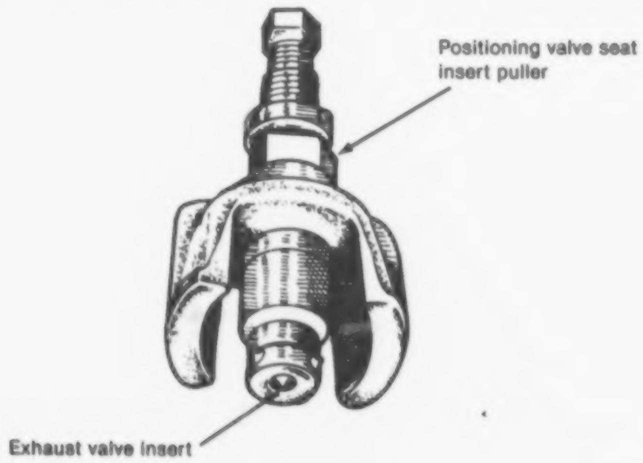
J. Injection nozzle removal tools (diesel)



K. Injection nozzle cleaning kit (diesel)

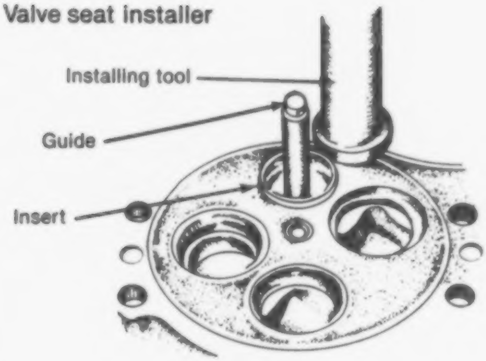


L. Valve seat remover

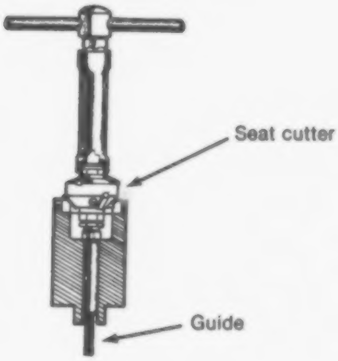

Positioning valve seat insert puller
Exhaust valve insert

INFORMATION SHEET

M. Valve seat installer



N. Carbide valve seat cutter



V. **Test equipment and functions**

A. Cylinder compression gauge — Measures cylinder pressure

B. Cylinder bore gauge — Checks the roundness or taper of a cylinder

C. Ring groove wear gauge — Measures the amount of wear in the piston ring grooves

D. Piston pin bore gauges — Measure piston pin bore for precision fit

E. Plastigage® — Determines engine bearing clearance

F. Valve spring tester — Checks the strength of valve springs

G. Injector nozzle tester — Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift

INFORMATION SHEET

H. Injection pump test stand — Tests and checks calibration of diesel fuel injection pump

(NOTE: An injection pump tester tests leakage, vacuum, pressure, and delivery used to make idle and torque control adjustments.)

I. Dynamometer — Applies a load to engine to measure engine horsepower and fuel consumption

J. Manometer — Checks very low pressures and vacuum

K. Battery hydrometer — Checks the specific gravity of a battery

L. Thermostat tester — Checks the temperature at which the thermostat starts to open

M. Radiator and cap tester — Checks the radiator and cap for leaks and correct opening pressure

N. Pyrometer — Instrument for measuring high temperatures beyond the range of a mercurial thermometer

O. Multimeter — A tester that combines voltmeter, ampmeter and ohmmeter into one unit

(NOTE: The voltmeter on some units can check AC and DC volts.)

VI. **Service tools and functions**

A. Valve refacer — Grinds an exact angle on the face of a valve

B. Valve seat grinder — Used to reseat valves with both rough and finishing grinding stones

C. Valve spring compressor — Compresses the spring when removing or installing the valve

D. Valve guide reamer — Removes small amount of metal from valve guides, so a valve guide insert can be installed

(NOTE: A valve guide reamer is ideal for cleaning carbon from used guides.)

E. Cylinder liner puller-installer — Hydraulic or manual tool used to remove or install cylinder liners

F. Cylinder ridge reamer — Removes the ring ridges found at the top of a cylinder or liner

INFORMATION SHEET

G. Cylinder deglazer — Used to deglaze and finish the cylinder or cylinder liner bore

(NOTE: Stone, pad, and brush types of cylinder deglazers are available.)

H. Piston ring expander — Used to remove or install piston rings without damage

I. Piston ring compressor — Used to compress the piston rings when installing pistons into the cylinder

J. Injection nozzle removal tools — Removal and installation kit for some injection nozzles

(NOTE: A typical kit includes hose clamp pliers, nozzle puller, bore cleaning tool, and a guide.)

K. Injection nozzle cleaning kit — Kit of tools designed to service one particular make of nozzle

(NOTE: Kits usually include cleaning wires, brushes, drills, and lapping compounds.)

L. Carbide valve seat cutter — Tool used to cut new angles, or dress up valve seat

M. Valve seat remover — Tool used to remove valve seat inserts from the cylinder head

N. Valve seat installer — Tool used to install valve seat inserts in the cylinder head

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

JOB SHEET #1 — CHECK COMPRESSION WITH A CYLINDER COMPRESSION GAUGE

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Appropriate hand tools
4. Cylinder compression gauge
5. Compression adapter for engine to be tested
6. Shop engine that can be operated
7. Service manual for engine to be tested

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Put on safety glasses.
2. Start engine and bring the engine up to operating temperature.
3. Shut engine off.
4. Remove the injection line and the injector from the first cylinder to be tested.
5. Clean the injector bore or sleeve with the recommended tool.

   (CAUTION: Keep as much foreign material from going into cylinder as possible.)

6. Crank the engine a few revolutions to blow out the carbon.

   (NOTE: Put the engine in the no-fuel position while cranking to prevent engine from starting.)

   Obtain instructor's initials here ____________ before proceeding to next step.

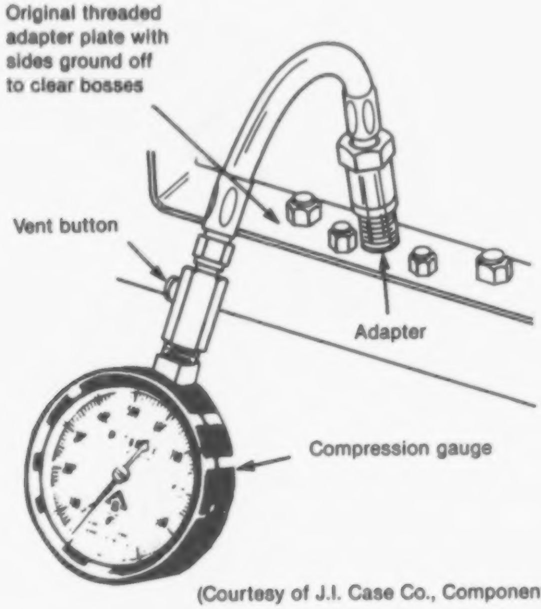
7. Place a new gasket in the bore (if used).
8. Put manufacturer's specification for correct torque of injector into cylinder head here ____________.

JOB SHEET #1

9. Install and tighten the correct adapter into cylinder head.

10. Install compression gauge to the adapter as shown. (Figure 1)

FIGURE 1


Original threaded
adapter plate with
sides ground off
to clear bosses
Vent button
Adapter
Compression gauge

(Courtesy of J.I. Case Co., Components Division)

11. Put manufacturer's specifications for amount of compression of the engine being tested here ____________.

12. Operate the engine at recommended speed until the compression gauge stabilizes.

13. Read and compare the compression pressure with the specification shown in your service manual.

14. Record the pressure from the engine here ____________.

    Obtain instructor's initials here ____________ before proceeding to next step.

15. Remove compression gauge and adapter from engine.

16. Install injector and injection line.

17. Check the remaining cylinder as outlined above.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

JOB SHEET #2 — CHECK BEARING CLEARANCE WITH PLASTIGAGE®

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Appropriate hand tools
4. Torque wrench
5. Strip of Plastigage®
6. Shop engine block with crankshaft (not installed)
7. Service manual for engine to be worked on
8. Air hose
9. Air blow gun

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Put safety glasses on.
2. Place engine to be worked on upside down (with crankcase up) on engine stand or blocks.
3. Remove main bearing caps from engine block.

   (NOTE: If caps are not numbered, mark caps and side of engine block for proper replacement.)

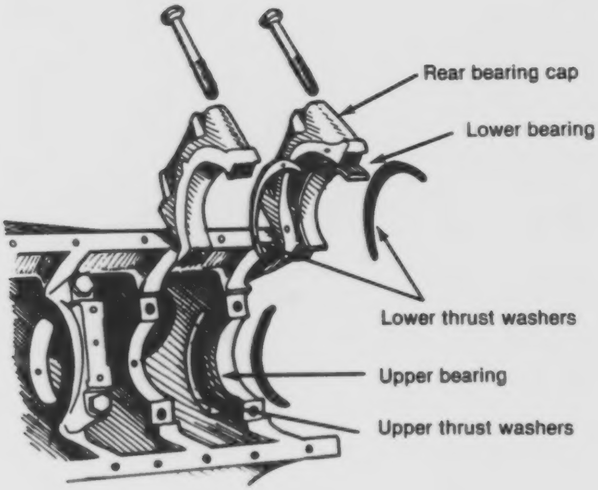
   Obtain instructor's initials here ______________ before proceeding to next step.
4. Place main bearing caps on work bench in order of removal.
5. Blow out crankcase and oil hole passages with a blow gun.
6. Clean main bearing saddles and caps with a clean shop towel.
7. Clean main bearing shells of any dirt or lubricant.
8. Check service manual for correct sequence for installing main bearing into block and caps.

   (NOTE: Check thrust bearing location.)

JOB SHEET #2

9. Install main bearing shells into engine block and caps, and thrust bearing in correct location. (Figure 1)

FIGURE 1



10. Clean crankshaft with compressed air and a clean shop towel.
11. Install crankshaft into engine block as outlined in service manual.

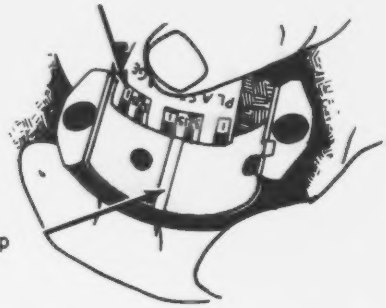
    (NOTE: Clean crankshaft and journals.)
12. Look in service manual for torque specification, and write the amount of torque for main bearings here ____________.
13. Torque all main bearing caps to specification in sequence.
14. Check crankshaft for freeness after torquing.

    Obtain instructor's initials here ____________ before proceeding to next step.
15. Look in service manual for bearing clearance specification and record here ____________.
16. Remove only one main bearing cap.
17. Place a suitable length of Plastigage® across the bearing surface.
18. Install main bearing cap and torque to specifications.
19. Remove the same main bearing cap that was torqued into place in step 18.

JOB SHEET #2

20. Measure the flattened Plastigage® with the scale on the original Plastigage® envelope. (Figure 2)

FIGURE 2



21. Record measurement here ____________.

22. Compare your measurements with specification.

    Obtain instructor's initials here ____________ before proceeding to next step.

23. Remove Plastigage® from bearing.

    (CAUTION: Do not damage bearing surface when removing Plastigage®.)

24. Clean bearing and crankshaft journal again.

25. Lubricate bearing shell and crankshaft journal.

26. Install main bearing cap onto engine block.

27. Torque to specification in sequence.

28. Check crankshaft for freeness at this point.

29. Measure remaining main bearings in the method mentioned above.

    Obtain instructor's initials here ____________ before proceeding to next step.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

JOB SHEET #3 — TEST RADIATOR WITH A RADIATOR TESTER

A. Tools and materials

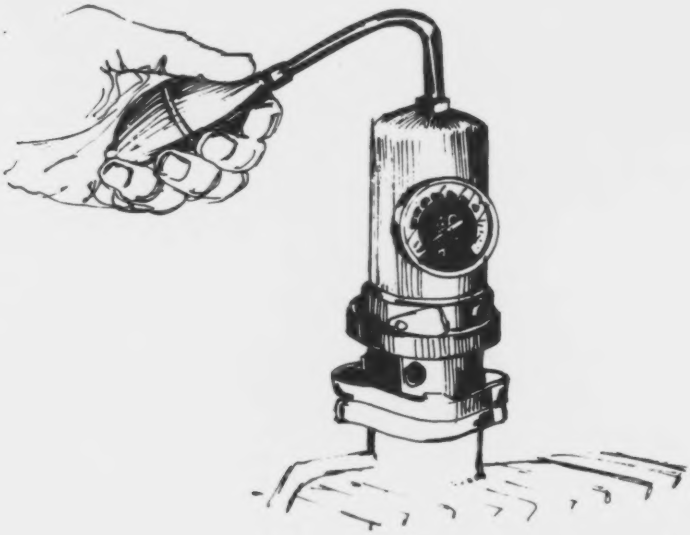
1. Safety glasses
2. Clean shop towels
3. Radiator and cap tester
4. Shop equipment with a radiator

B. Procedure

(CAUTION: Follow all shop safety precautions.)

1. Put safety glasses on.
2. Fill radiator with coolant.
3. Install radiator tester onto radiator. (Figure 1)

FIGURE 1



JOB SHEET #3

4. Check service manual for coolant operating pressure before proceeding.

5. Pressurize the system about 10 percent over normal operating pressure.

   (CAUTION: Take care not to overpressurize the system.)

   (NOTE: Excessive pressure can swell the radiator core tubes, which would restrict airflow through radiator.)

6. Check the radiator for any leaks.

7. Mark the holes or area of the leak with chalk.

8. If radiator is attached to a piece of equipment, check the rest of the cooling system for leaks.

9. Relieve pressure from the radiator.

10. Remove radiator tester from radiator.

    Obtain instructor's initials here ____________.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

JOB SHEET #4 — TEST A THERMOSTAT

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Container for water
4. Hot plate
5. Thermometer
6. Thermostat

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Put safety glasses on.
2. Place container of water onto hot plate.
3. Turn hot plate on.
4. Place the thermometer into the container.

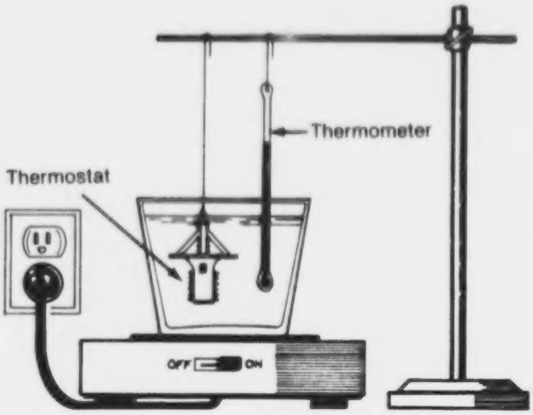
   (NOTE: Do not allow thermometer to touch bottom of container or a false reading will result.)

5. Tie a piece of string onto the thermostat.

JOB SHEET #4

6. Suspend the thermostat in the water. (Figure 1)

FIGURE 1



7. Stir the water to maintain an even temperature throughout the container.

8. Watch thermometer closely.

9. Watch the thermostat.

10. Check temperature at which the thermostat starts to open, and record temperature here ______________.

11. Check temperature at which the thermostat is fully open, and record temperature here ______________.

12. Check service specification for correct operating temperatures and record them here ______________.

    (NOTE: If thermostat is bad, replace it. If the thermostat is good, follow service manual procedure for cleaning and install.)

13. Put all materials away after they have cooled off.

    Obtain instructor's initials here ______________.

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

PRACTICAL TEST
JOB SHEET #1 — CHECK COMPRESSION WITH A CYLINDER COMPRESSION GAUGE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Put on safety glasses.	______	______
3. Brought engine to operating temperature.	______	______
4. Shut engine down.	______	______
5. Removed injector.	______	______
6. Cleaned injector bore.	______	______
7. Cleaned carbon out of cylinder.	______	______
8. Recorded manufacturer's specifications.	______	______
9. Installed adapter.	______	______
10. Installed compression gauge.	______	______
11. Recorded manufacturer's specification for compression.	______	______
12. Operated engine to recommended speed.	______	______
13. Read and compared pressure.	______	______
14. Recorded pressure reading.	______	______
15. Removed gauge and adapter.	______	______
16. Installed injector and lines.	______	______
17. Checked remaining cylinder.	______	______
18. Checked in/put away tools and materials.	______	______
19. Cleaned the work area.	______	______
20. Used proper tools correctly.	______	______
21. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
22. Practiced safety rules throughout procedure.	______	______
23. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Any cylinder low on compression was located.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

PRACTICAL TEST
JOB SHEET #2 — CHECK BEARING CLEARANCE WITH PLASTIGAGE®

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety glasses.	______	______
3. Removed main bearing caps.	______	______
4. Cleaned block and crankcase.	______	______
5. Cleaned bearing shells.	______	______
6. Installed main bearings.	______	______
7. Installed crankshaft.	______	______
8. Checked service manual for torque.	______	______
9. Torqued all main bearing caps.	______	______
10. Removed one cap.	______	______
11. Installed Plastigage®.	______	______
12. Installed cap and torqued.	______	______
13. Removed cap.	______	______
14. Took Plastigage® measurement.	______	______
15. Lubricated and replaced cap.	______	______
16. Retorqued cap to specification.	______	______
17. Checked clearance on remaining bearings.	______	______
18. Checked in/put away tools and materials.	______	______
19. Cleaned the work area.	______	______
20. Used proper tools correctly.	______	______
21. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
22. Practiced safety rules throughout procedure.	______	______
23. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Bearing clearances are within specifications.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

PRACTICAL TEST
JOB SHEET #3 — TEST RADIATOR WITH A RADIATOR TESTER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety glasses.	______	______
3. Filled radiator.	______	______
4. Installed radiator tester.	______	______
5. Pressurized radiator.	______	______
6. Checked for leaks.	______	______
7. Marked leak.	______	______
8. Removed radiator tester.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Leaks in radiator were found.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

PRACTICAL TEST
JOB SHEET #4 — TEST A THERMOSTAT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety glasses.	______	______
3. Put container of water on hot plate.	______	______
4. Turned hot plate on.	______	______
5. Put thermometer in water.	______	______
6. Suspended thermostat in water.	______	______
7. Recorded opening temperature.	______	______
8. Recorded fully open temperature.	______	______
9. Checked temperatures with service manual specification.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Thermostat is reuseable or faulty.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms related to test equipment and service tools with the correct definitions.

_____a. The act of analyzing, testing, and measuring the engine to remedy the cause of trouble

_____b. To enlarge or dress out a hole or bore

_____c. To recognize by signs or symptoms

_____d. Two dissimilar wires joined at one end, and used to measure temperature differences

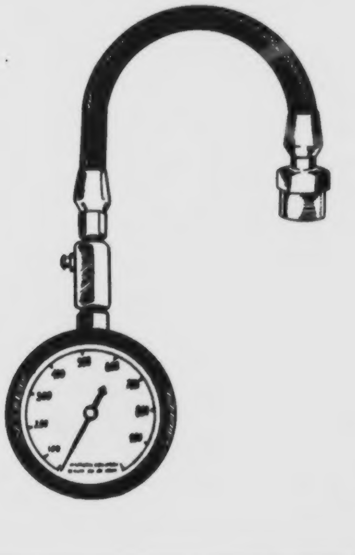
1. Diagnose
2. Ream
3. Thermocouple
4. Troubleshooting

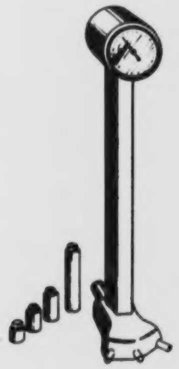
2. Distinguish between test equipment and service tools by placing an "X" beside the function of test equipment.

_____a. To diagnose the engine

_____b. To repair the engine

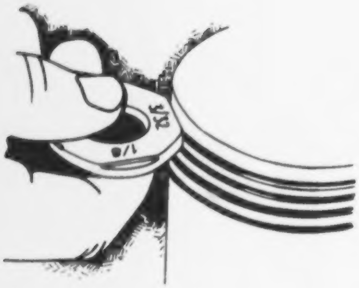
3. Identify the types of test equipment.

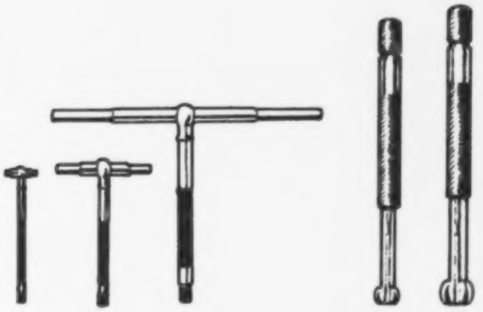




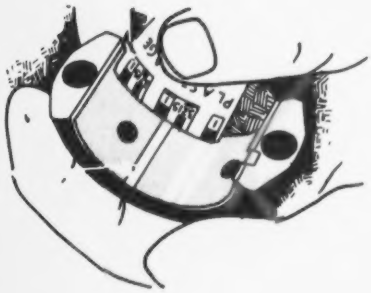
a. ______________________________ b. ______________________________

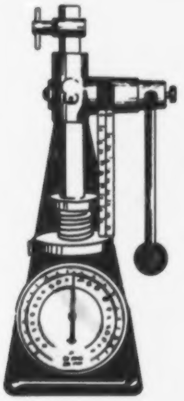
TEST



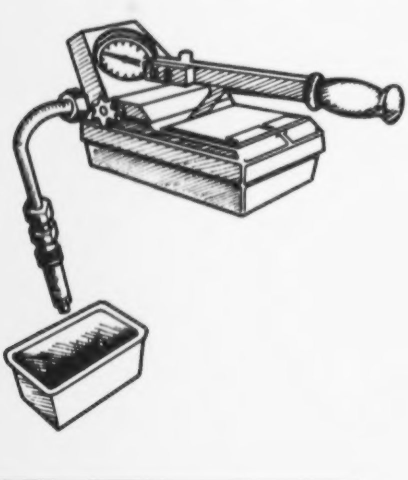


c. ______________________________ d. ______________________________



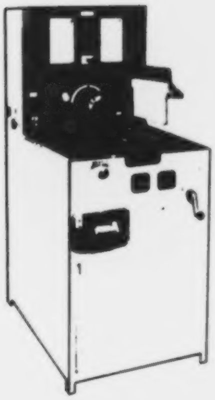


e. ______________________________ f. ______________________________

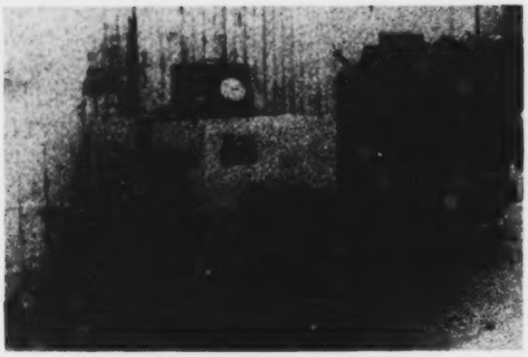


g. ______________________________

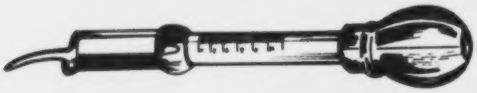
TEST



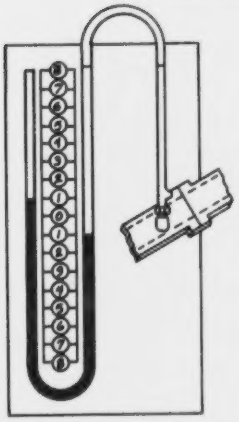
h. ____________________



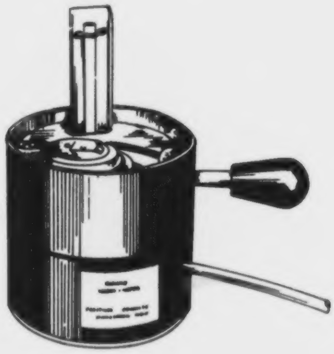
i. ____________________



j. ____________________

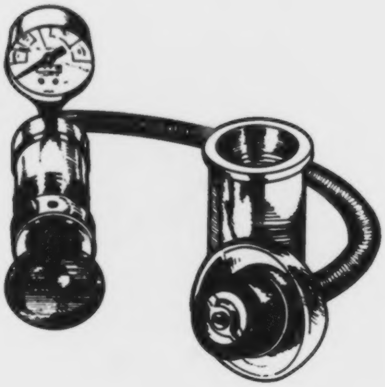


k. ____________________

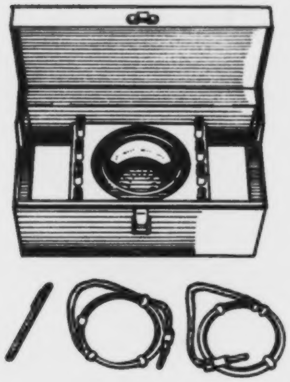


l. ____________________

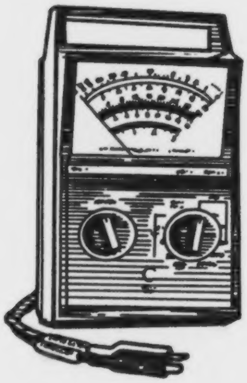
TEST



m. ______________________________



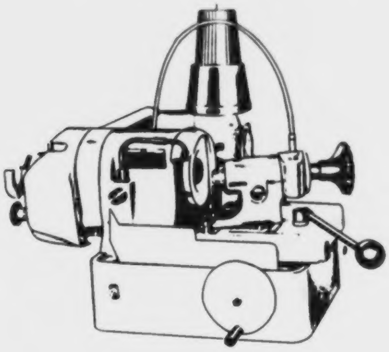
n. ______________________________

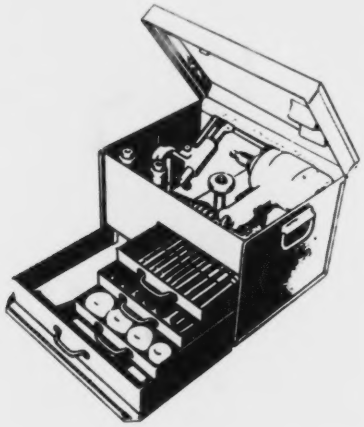


o. ______________________________

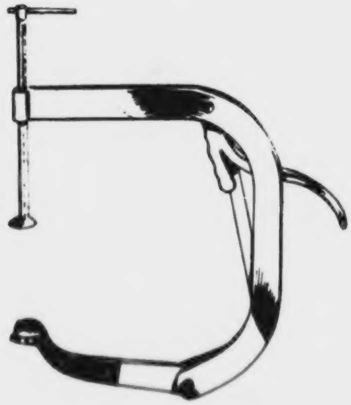
TEST

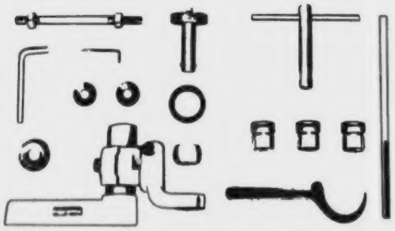
4. Identify the types of service tools.





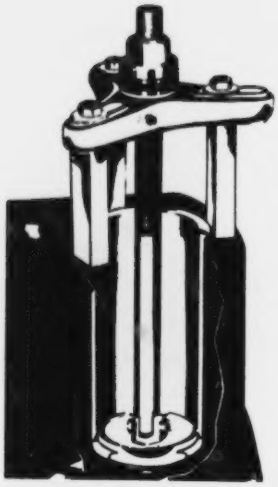
a. ______________________________ b. ______________________________



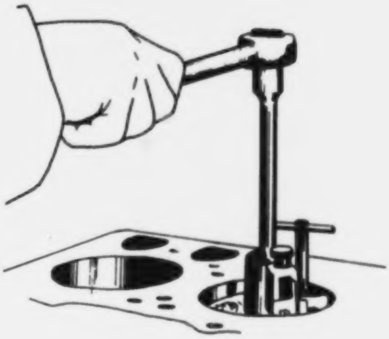


c. ______________________________ d. ______________________________

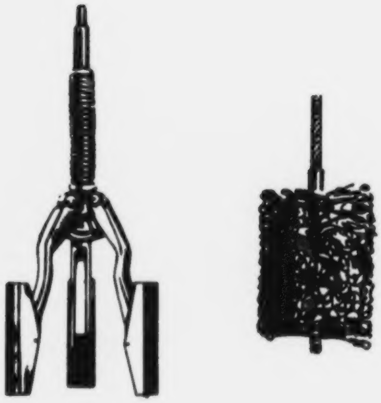
TEST



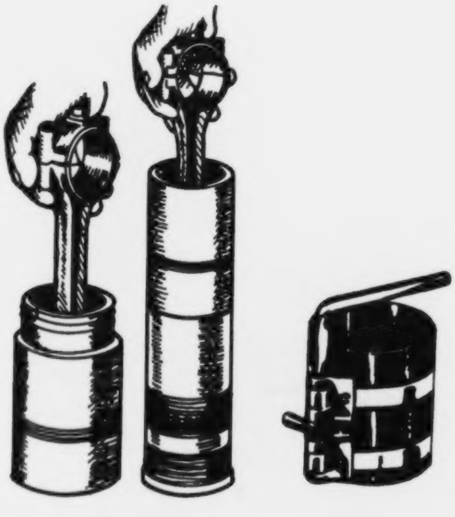
e. ______________________________



f. ______________________________

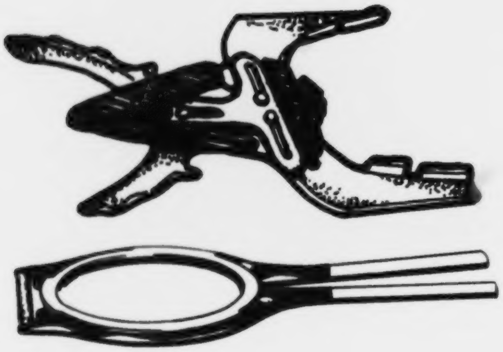


g. ______________________________

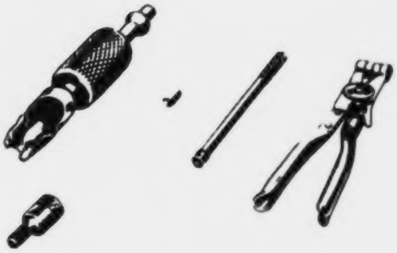


h. ______________________________

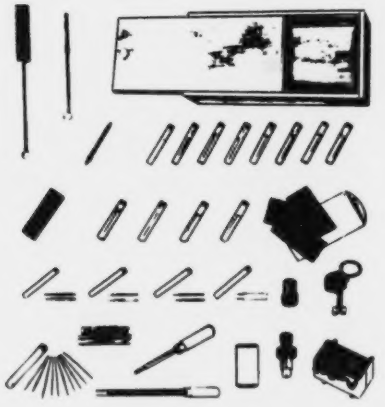
TEST



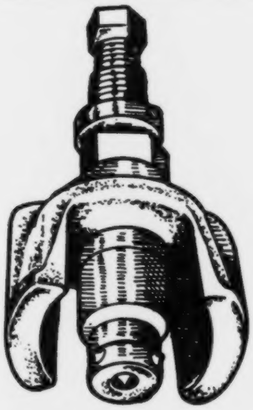
i. ______________________________



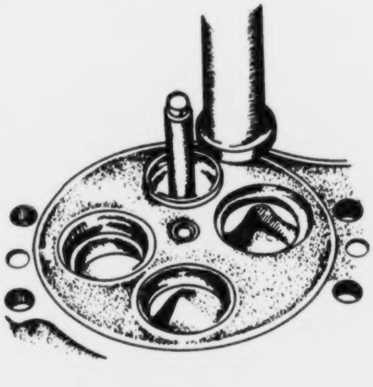
j. ______________________________



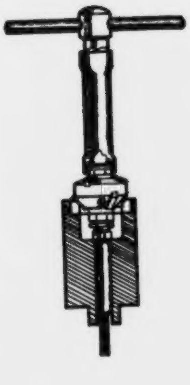
k. ______________________________



l. ______________________________



m. ______________________________



n. ______________________________

TEST

5. Match the test equipment on the right with the correct functions.

_____a. Measures cylinder pressure

_____b. Checks the roundness or taper of a cylinder

_____c. Measures the amount of wear in the piston ring grooves

_____d. Measure piston pin bore for precision fit

_____e. Determines engine bearing clearance

_____f. Checks the strength of valve springs

_____g. Checks the condition of needle valve and seat, spray pattern, cracking pressure of nozzle, leak off through nozzle, and nozzle valve lift

_____h. A tester that combines voltmeter, ampmeter and ohmmeter into one unit

_____i. Applies a load to engine to measure engine horsepower and fuel consumption

_____j. Checks very low pressures and vacuum

_____k. Checks the specific gravity of a battery

_____l. Checks the temperature at which the thermostat starts to open

_____m. Checks the radiator and cap for leaks and correct opening pressure

_____n. Instrument for measuring temperatures beyond the range of a mercurial thermometer

_____o. Tests and checks calibration of diesel fuel injection pump

1. Battery hydrometer
2. Cylinder bore gauge
3. Cylinder compression gauge
4. Dynamometer
5. Injection nozzle tester
6. Injection pump test stand
7. Manometer
8. Multimeter
9. Piston pin bore gauges
10. Plastigage®
11. Pyrometer
12. Radiator and cap tester
13. Ring groove wear gauge
14. Thermostat tester
15. Valve spring tester

TEST

6. Match the service tools on the right with the correct functions.

______a. Grinds an exact angle on the face of a valve

______b. Used to reseat valves with both rough and finishing grinding stones

______c. Compresses the spring when removing or installing the valve

______d. Removes small amount of metal from valve guides, so a valve guide can be installed

______e. Tool used to move valve seat inserts from cylinder head

______f. Hydraulic or manual tool used to remove or install cylinder liners

______g. Removes the ring ridges found at the top of a cylinder or liner

______h. Used to deglaze and finish the cylinder or cylinder liner bore

______i. Used to remove or install piston rings without damage

______j. Used to compress the piston rings when installing pistons into the cylinder

______k. Removal and installation kit for some injection nozzles

______l. Kit of tools designed to service one particular make of nozzle

______m. Tool used to cut new angles, or dress up valve seat

______n. Tool used to install valve seat inserts in the cylinder head

1. Carbide valve seat cutter
2. Cylinder deglazer
3. Cylinder liner puller-installer
4. Cylinder ridge reamer
5. Injection nozzle cleaning kit
6. Injection nozzle removal tools
7. Piston ring expander
8. Piston ring compressor
9. Valve guide reamer
10. Valve refacer
11. Valve seat grinder
12. Valve seat installer
13. Valve seat remover
14. Valve spring compressor

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

7. Demonstrate the ability to:

   a. Check compression with a compression gauge. (Job Sheet #1)

   b. Check bearing clearance with Plastigage®. (Job Sheet #2)

   c. Test radiator with a radiator tester. (Job Sheet #3)

   d. Test a thermostat. (Job Sheet #4)

TEST EQUIPMENT AND SERVICE TOOLS
UNIT III-A

ANSWERS TO TEST

1. a. 4
   b. 2
   c. 1
   d. 3

2. a

3. a. Cylinder compression gauge
   b. Cylinder bore gauge
   c. Ring groove wear gauge
   d. Piston pin bore gauges
   e. Plastigage®
   f. Valve spring tester
   g. Injection nozzle tester
   h. Injection pump test stand
   i. Dynamometer
   j. Battery hydrometer
   k. Manometer
   l. Thermostat tester
   m. Radiator and cap tester
   n. Pyrometer
   o. Multimeter

4. a. Valve refacer
   b. Valve seat grinder
   c. Valve spring compressor
   d. Valve guide reamer
   e. Cylinder liner puller-installer
   f. Cylinder ridge reamer
   g. Cylinder deglazer
   h. Piston ring compressor
   i. Piston ring expander
   j. Injection nozzle removal tools
   k. Injection nozzle cleaning kit
   l. Valve seat remover
   m. Valve seat installer
   n. Carbide valve seat cutter

5. a. 3
   b. 2
   c. 13
   d. 9
   e. 10
   f. 15
   g. 5
   h. 8
   i. 4
   j. 7
   k. 1
   l. 14
   m. 12
   n. 11
   o. 6

ANSWERS TO TEST

6.

a.	10	f.	3	k.	6
b.	11	g.	4	l.	5
c.	14	h.	2	m.	1
d.	9	i.	7	n.	12
e.	13	j.	8		

7. Performance skills evaluated to the satisfaction of the instructor.

FASTENERS
UNIT IV-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify typical fasteners, discuss how bolts and threads are measured, and select qualities of satisfactory fasteners. The student should also be able to select methods used to remove seized nuts and select tools used to restore threads. Competencies will be demonstrated by completing the assignment sheets, job sheets, and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to fasteners with the correct definitions.
2. Select qualities of satisfactory fasteners.
3. Identify typical fasteners.
4. Identify typical bolt head styles.
5. Identify bolt and thread measuring terms with their locations.
6. Select true statements concerning SAE grade and metric bolts and nuts.
7. Identify typical nuts.
8. Identify special purpose nuts with locking or self-locking features.
9. Select methods used to remove a seized nut.
10. Identify types of washers.

OBJECTIVE SHEET

11. Select tools used to restore bolt threads.
12. Select tools used to restore internal threads.
13. Identify devices for locking nuts or bolts.
14. Identify types of machine screw head designs.
15. Identify types of snap rings.
16. Match wrench with the correct size bolt (standard). (Assignment Sheet #1)
17. Match wrench with the correct size bolt (standard). (Assignment Sheet #2)
18. Measure bolt and threads. (Assignment Sheet #3)
19. Match wrench with the correct size bolt (metric). (Assignment Sheet #4)
20. Match wrench with the correct size bolt (metric). (Assignment Sheet #5)
21. Demonstrate the ability to:
    a. Draw a twist drill to correct center, and extract a broken bolt, stud, or screw. (Job Sheet #1)
    b. Cut external threads. (Job Sheet #2)
    c. Cut internal threads. (Job Sheet #3)

FASTENERS
UNIT IV-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets and handouts.

F. Discuss information, handouts, and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss the different grades of bolts with Handout #1 and Handout #2.
2. Discuss using the proper wrench with the correct size bolt as outlined in Handout #1 and Handout #2.
3. Show students the different sizes of bolts and nuts (standard and metric).
4. Have students size different threads (standard and metric).
5. Have a representative of a local distributor provide more information on fasteners.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fastener Facts.* Dallas, TX: Bowman Distribution, 1985.

B. *Identifying Metric Fasteners.* East Peoria, IL: Caterpillar Tractor Co., 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

1. *Introduction to Fasteners* and *Introduction to Torque*
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602

2. *Fastener Products*
Barnes Group Incorporated
850 East 72nd Street
Cleveland, OH 44103
(216) 391-7200

B. **Filmstrip**

1. *Fasteners* — 130 slides
Deere and Company
Distribution Service Center
1400 Third Avenue
Moline, IL 61265

2. *Metrics for Auto Mechanics*, 2 cassettes, 2 filmstrips
Teacher's Aids Incorporated
Box 1798
Costa Mesa, CA 92626-0798
(714) 548-9321

FASTENERS
UNIT IV-A

INFORMATION SHEET

I. **Terms and definition**

   A. Bolt — Metal rod or pin that has a head at one end, a screw thread at the other end, and is secured by a nut; used for fastening objects together

   B. Cap screw — An externally threaded fastener which must be torqued by its head into a tapped hole

   C. Die — Internally threaded screw cutting tool; used for forming external screw threads

   D. Fastener — Device used to secure or hold together separate items

   E. SAE — Society of Automotive Engineers

   F. Screw — Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

   G. Stud — Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

   H. Tap — Tool for forming an internal screw thread

II. **Qualities of satisfactory fasteners**

   A. Strength

   B. Reusability

   C. Easy to remove

   D. Withstand vibration

   E. Long lasting

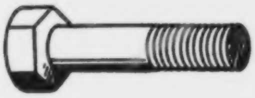
   F. Corrosion resistant

   G. Temperature resistant

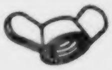
INFORMATION SHEET

III. Typical fasteners

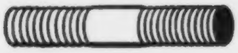
A. Hex head bolt



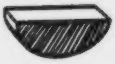
B. Wing nut



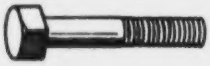
C. Stud



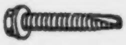
D. Woodruff key



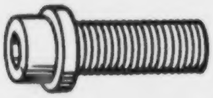
E. Cap screw

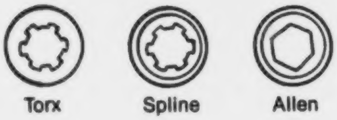


F. Tapping screw

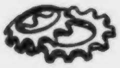


G. Socket head bolt

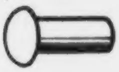




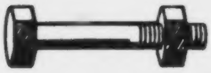
H. Toothed lock washer



I. Rivet

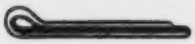


J. Bolt and nut

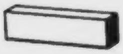


INFORMATION SHEET

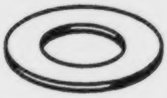
K. Cotter pin



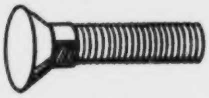
L. Square key



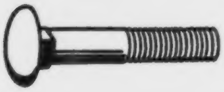
M. Flat washer



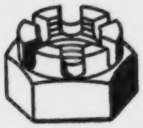
N. Plow bolt



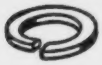
O. Carriage bolt



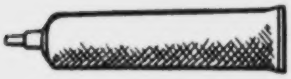
P. Castle nut



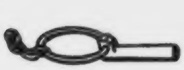
Q. Lock washer



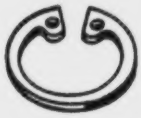
R. Adhesive (Locktight)



S. Lock pin

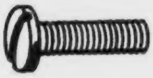


T. Snap ring

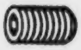


INFORMATION SHEET

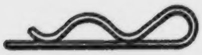
U. Machine screw



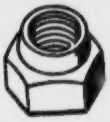
V. Set screw



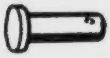
W. Spring lock pin



X. Locking nut

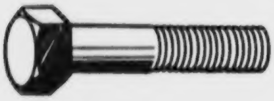


Y. Clevis pin

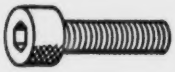


IV. Typical bolt head styles

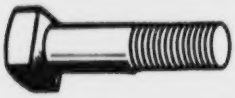
A. Hex head



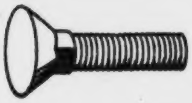
B. Hex socket head (allen)



C. Square head cap screw

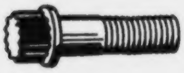


D. Plow

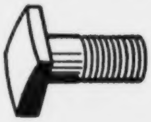


INFORMATION SHEET

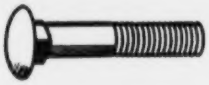
E. 12-Point Head



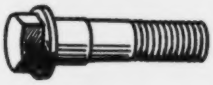
F. Askew head



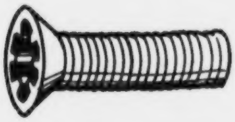
G. Carriage



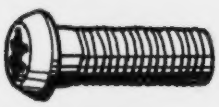
H. Hex flange screw



I. Torx

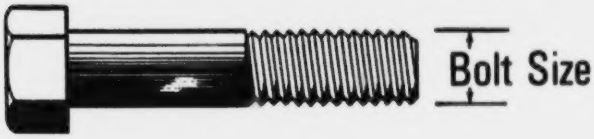


J. Spline

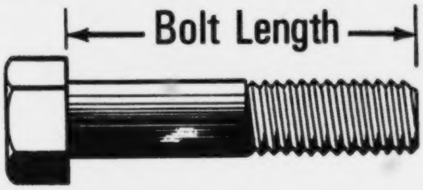


V. **Measuring bolts and threads** (Transparency 1)

A. Size of bolt is determined by measuring the diameter of the thread end.



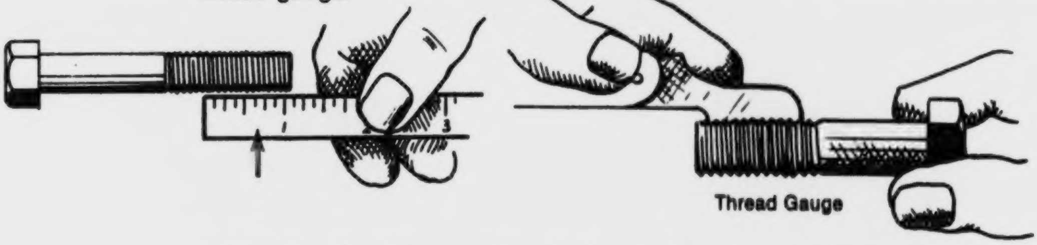
B. Length of bolt is determined by measuring the distance from bottom of the head to the end of the threads.



(NOTE: Some carriage bolts with round, flat, tapered heads are measured from the top of the head to the end of the threads.)

INFORMATION SHEET

C. Number of threads per inch is determined by measuring with a ruler or a thread gauge.



(NOTE: American National Standards established the unified screw thread standard. Coarse threads are U.S. standard and fine threads are S.A.E. threads.)

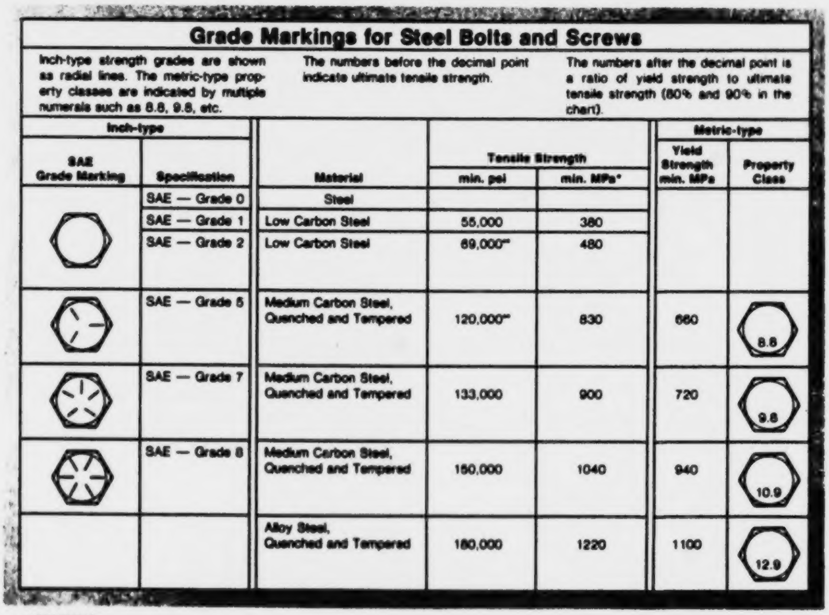
VI. **SAE grade and metric bolts and nuts** (Transparency 2)

A. SAE grade and metric bolts are identified by markings on the heads of the bolt.

B. SAE grade bolts use slashes for identification.

Example: Grade 1 and 2 — No slashes
Grade 5 — Three slashes
Grade 7 — Five slashes
Grade 8 — Six slashes

C. Metric bolts use numbers for identification which correspond to bolt strength; increasing numbers represent increasing strength.



Grade Markings for Steel Bolts and Screws

Inch-type strength grades are shown as radial lines. The metric-type property classes are indicated by multiple numerals such as 8.8, 9.8, etc.

The numbers before the decimal point indicate ultimate tensile strength.

The numbers after the decimal point is a ratio of yield strength to ultimate tensile strength (80% and 90% in the chart).

Inch-type			Tensile Strength		Metric-type	
SAE Grade Marking	Specification	Material	min. psi	min. MPa*	Yield Strength min. MPa	Property Class
	SAE — Grade 0	Steel				
	SAE — Grade 1	Low Carbon Steel	55,000	380		
	SAE — Grade 2	Low Carbon Steel	69,000**	480		
	SAE — Grade 5	Medium Carbon Steel, Quenched and Tempered	120,000**	830	660	8.8
	SAE — Grade 7	Medium Carbon Steel, Quenched and Tempered	133,000	900	720	9.8
	SAE — Grade 8	Medium Carbon Steel, Quenched and Tempered	150,000	1040	940	10.9
		Alloy Steel, Quenched and Tempered	180,000	1220	1100	12.9

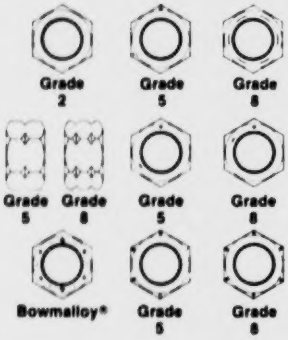
* megapascal

**Small size bolts. Larger bolts may have lower values

(Courtesy of Caterpillar, Inc.)

INFORMATION SHEET

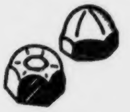
D. Nuts are also graded so they may be mated with the same grade of fastener.


Grade 2
Grade 5
Grade 8
Grade 5
Grade 8
Grade 5
Grade 8
Bowmalloy®
Grade 5
Grade 8

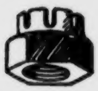
(Courtesy of Bowman Distribution, Barnes Group Inc.)

VII. **Typical nuts**

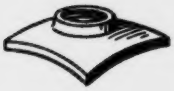
A. Acorn



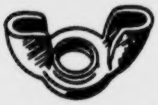
B. Castle



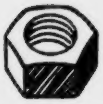
C. Spring



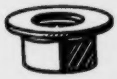
D. Wing



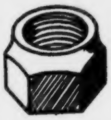
E. Hex



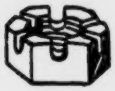
F. Flanged



G. Lock

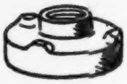


H. Slotted

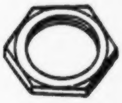


INFORMATION SHEET

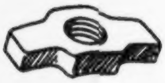
I. Weld



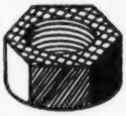
J. Panel



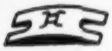
K. Specialty



L. Serrated

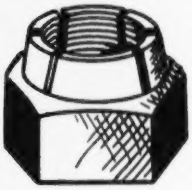


M. Single thread

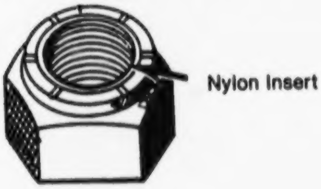


VIII. **Special purpose nuts with locking or self-locking features**

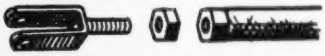
A. Prevailing torque lock



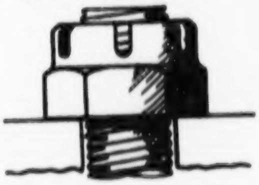
B. Plastic insert lock



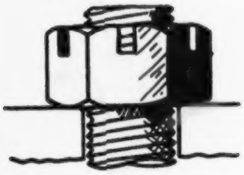
C. Jam



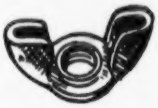
D. Castle



E. Slotted

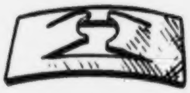


F. Wing

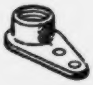


INFORMATION SHEET

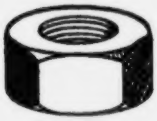
G. Speed



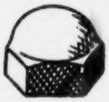
H. Anchor



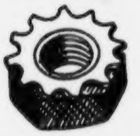
I. Chamfered (both sides)



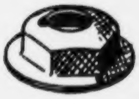
J. Cap



K. Flange-lock

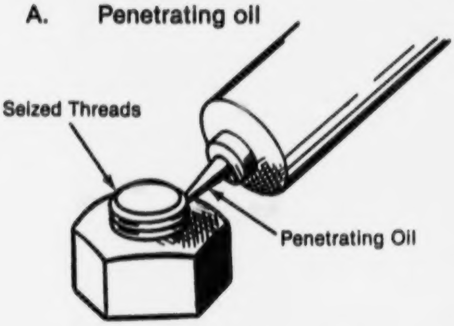


L. Pal

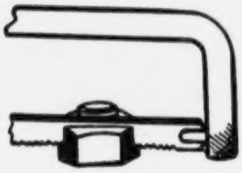


IX. Methods used to remove a seized nut

A. Penetrating oil

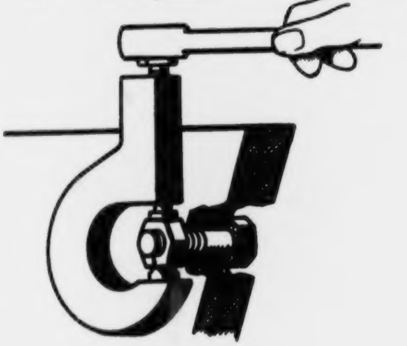

Seized Threads
Penetrating Oil

B. Hacksaw

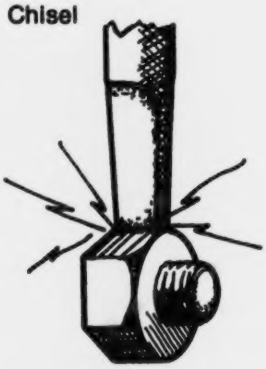


INFORMATION SHEET

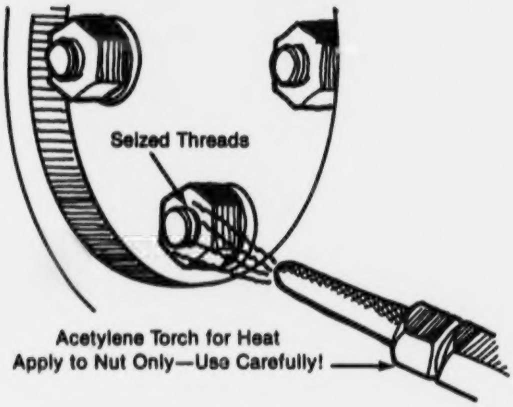
C. Nut-splitter



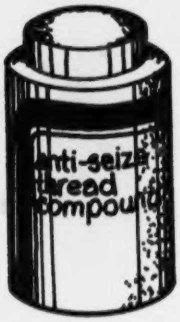
D. Chisel



E. Acetylene torch

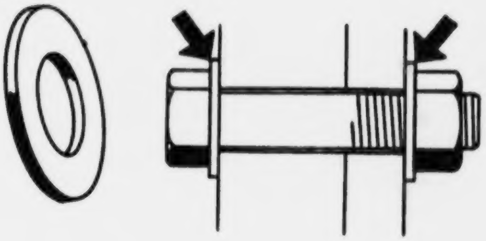

Seized Threads
Acetylene Torch for Heat
Apply to Nut Only—Use Carefully!

F. Anti-seize compound

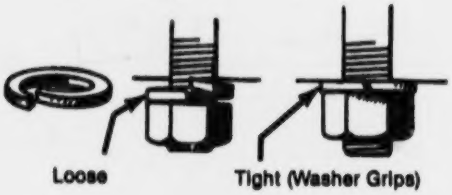

anti-seize
thread
compound

X. **Types of washers**

A. Flat

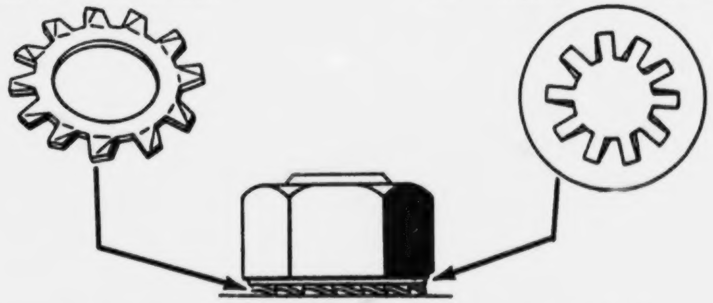


B. Lock

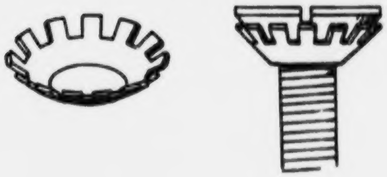

Loose
Tight (Washer Grips)

INFORMATION SHEET

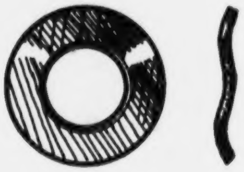
C. External toothed lock D. Internal toothed lock



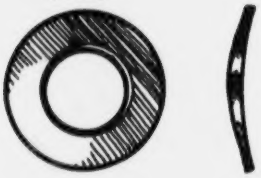
E. Countersunk external toothed



F. Wave (spring)

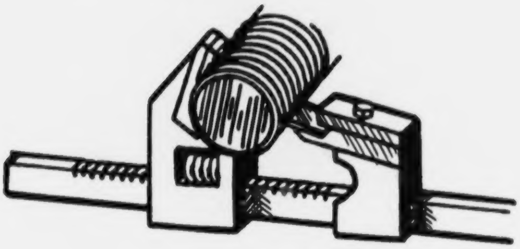


G. Spring

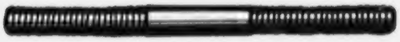


XI. **Tools used to restore bolt threads**

A. Rethreading tool

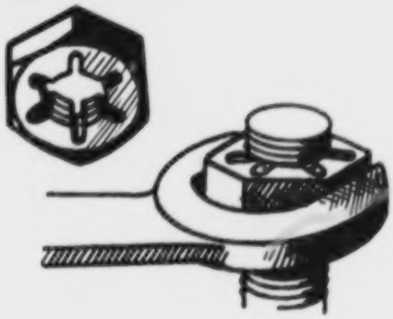


B. Thread file



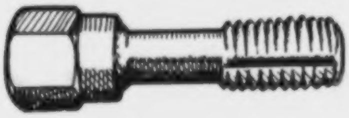
INFORMATION SHEET

C. Rethreading die

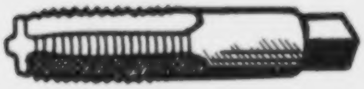


XII. Tools to restore internal threads

A. Internal thread chaser

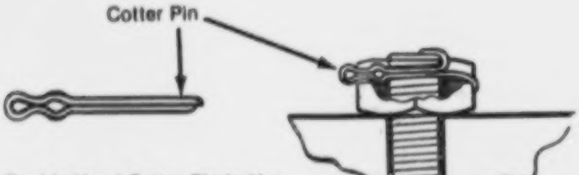


B. Hand tap

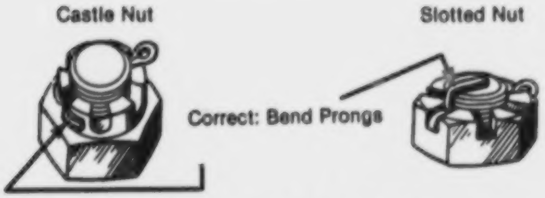


XIII. Devices for locking nuts or bolts

A. Cotter pins



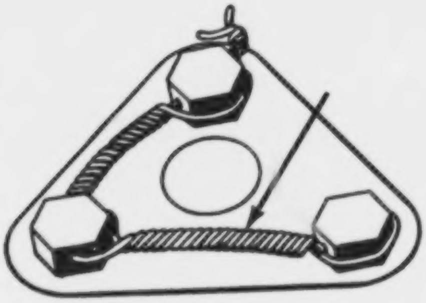
Double-Head Cotter Pin in Use


Castle Nut
Slotted Nut
Correct: Bend Prongs

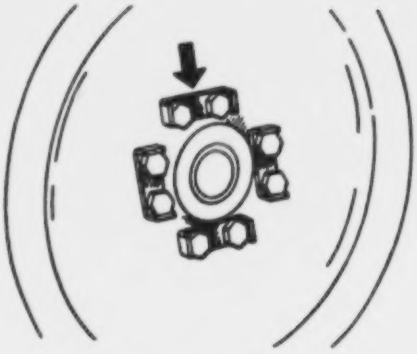
Cotter Pin Prongs Properly Bent Around
Castle Nut and a Slotted Nut

INFORMATION SHEET

B. Lock wire

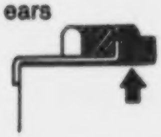


C. Flat metal locks

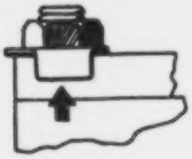


Flat Metal Locks Hold Flywheel Bolts in Place

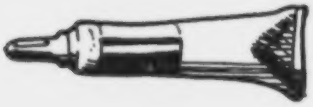
D. Lock ears



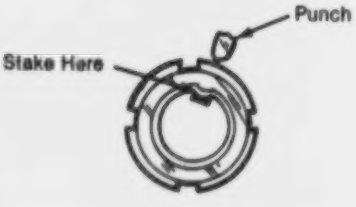
Lock Ears Properly Bent Into Place



E. Lock tight



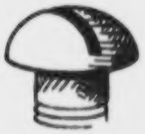
F. Staking nut



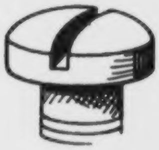
INFORMATION SHEET

XIV. Types of machine screw head designs

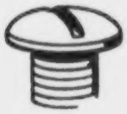
A. Round



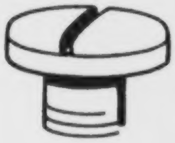
B. Fillister



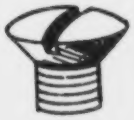
C. Truss



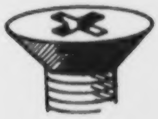
D. Pan



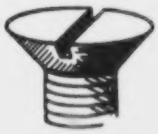
E. Oval



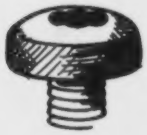
F. Cross recessed or phillips



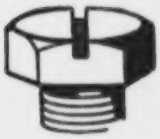
G. Flat



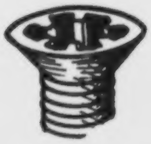
H. Clutch



I. Hex slotted



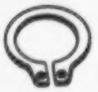
J. Torx

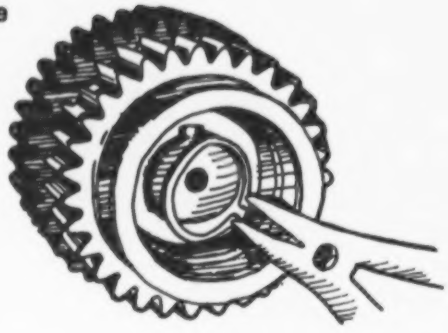


INFORMATION SHEET

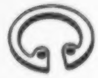
XV. Types of snap rings

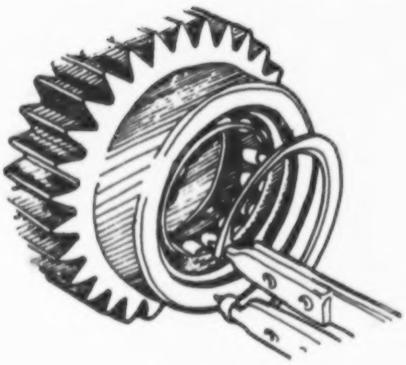
A. External hole



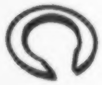


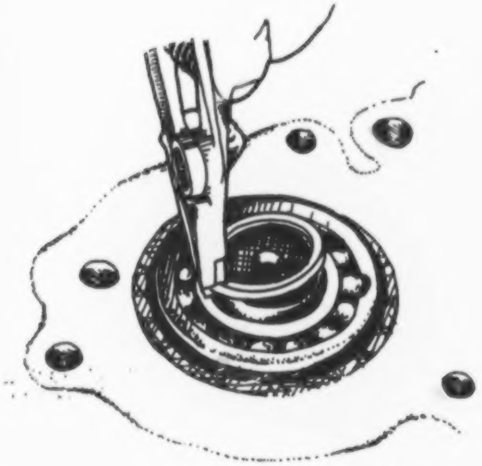
B. Internal hole





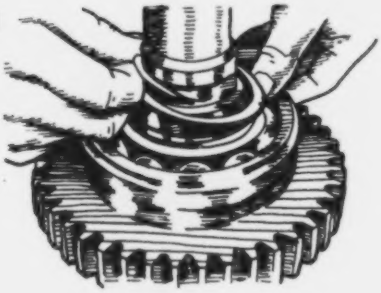
C. Lock ring



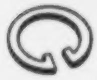


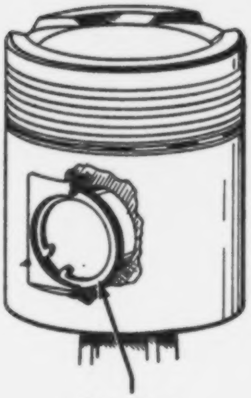
INFORMATION SHEET

D. Spirolox ring

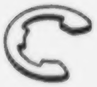


E. Internal prong



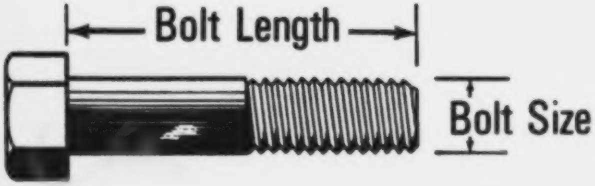


F. External "E"

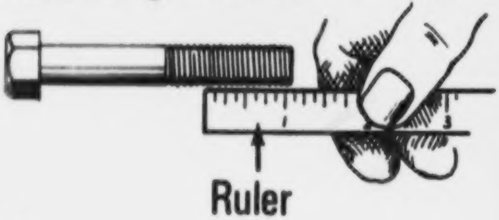


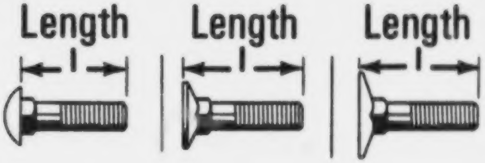
(NOTE: Most snap rings have a flat side and a round side. The rule for installing a snap ring is to put round side to the load.)

How to Measure Bolts and Threads

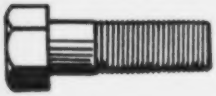

Bolt Length
Bolt Size

Measuring Threads Per Inch

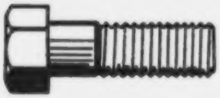



Length
Length
Length

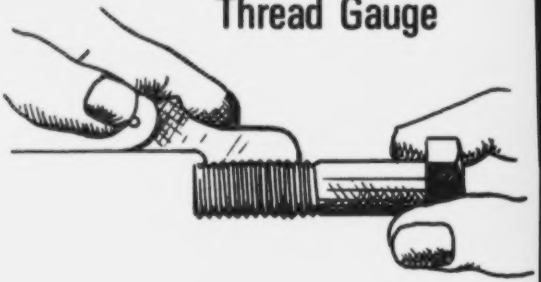
Fine Thread



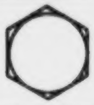
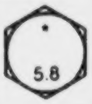
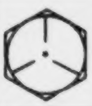
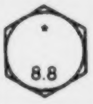
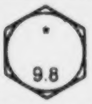
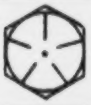
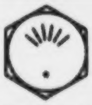
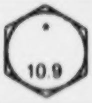
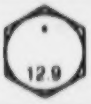
Coarse Thread



Thread Gauge



Head Marking Chart

Grade Marking	Specification	Material	Nominal Size, Dia. In.	Proof Load PSI (MPa)	Tensile Strength Min. PSI (MPa)
	SAE — Grade 1	Low carbon steel	1/4 thru 1½	33,000	60,000
	SAE — Grade 2	Low carbon steel	1/4 thru 3/4 over 3/4 to 1½	55,000 33,000	74,000 60,000
	Property Class 5.8	Low or medium carbon steel	M5 thru M24	55,100 (380)	75,400 (520)
	SAE — Grade 5	Medium carbon steel, quenched & tempered	1/4 thru 1 over 1 to 1½	85,000 74,000	120,000 105,000
	Property Class 8.8	Medium carbon steel, quenched & tempered	M17 thru M36	87,000 (600)	120,350 (830)
	Property Class 9.8	Medium carbon steel, quenched & tempered	M1.6 thru M16	94,250 (650)	130,500 (900)
	SAE — Grade 7	Medium carbon alloy steel, quenched & tempered, roll threaded after heat treatment	1/4 thru 1½	105,000	133,000
	SAE — Grade 8.2	Low carbon boron martensite steel, fully killed, fine grain, quenched & tempered	1/4 thru 1	120,000	150,000
	Property Class 10.9	Medium carbon alloy steel, quenched & tempered	M6 thru M36	120,350 (830)	150,800 (1040)
	Property Class 12.9	Medium carbon alloy steel, quenched & tempered	M1.6 thru M36	140,650 (970)	176,900 (1220)

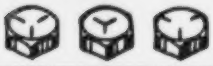
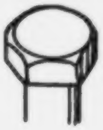
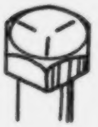
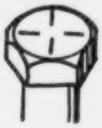
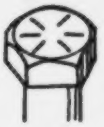
*Manufacturer's identification symbols are required per SAE (per ANSI on metric products)

(Courtesy of Bowman Distribution, Barnes Group Inc.)

FASTENERS
UNIT IV-A

HANDOUT #1 — TORQUE SPECIFICATION FOR BOLTS AND CORRECT (STANDARD) WRENCH SIZE

CAPSCREW MARKINGS AND TORQUE
(Standard)

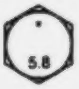
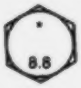
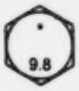
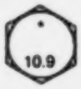
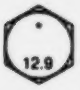
Minimum Tensil Strength	**64,000 psi**	**105,000 psi**	**133,000 psi**	**150,000 psi**
Quality of Material	**Indeterminate**	**Minimum Commercial**	**Medium Commercial**	**Best Commercial**
SAE Grade Number	**1 or 2**	**5**	**6**	**8**
Bolt Head Markings Manufacturer's marks may vary. These are all SAE Grade 5 (3-line). 				
Bolt Body Size (Inches)	**Torque (Foot pounds)**	**Torque (Foot pounds)**	**Torque (Foot pounds)**	**Torque (Foot pounds)**
1/4	5	7	10	10.5
5/16	9	14	19	22
3/8	15	25	34	37
7/16	24	40	55	60
1/2	37	60	85	92
9/16	53	88	120	132
5/8	74	120	167	180
3/4	120	200	280	296
7/8	190	302	440	473
1	282	466	660	714

BOLT SIZE (DIA.)	WRENCH SIZE
1/4"	7/16"
5/16"	1/2"
3/8"	9/16"
7/16"	5/8 or 11/16"
1/2"	3/4"
9/16"	13/16 or 7/8"
5/8"	15/16"
11/16"	1 or 1 1/16"
3/4"	1 1/8"
7/8"	1 1/4"
1"	1 1/2"

FASTENERS
UNIT IV-A

HANDOUT #2 — TORQUE SPECIFICATION FOR BOLTS AND CORRECT (METRIC) WRENCH SIZE

CAPSCREW MARKINGS AND TORQUE
(Metric)

Quality of Material	**Medium Carbon Steel**	**Medium Carbon Steel Tempered**	**Medium Carbon Steel Tempered**	**Medium Carbon Steel Alloy**	**Medium Carbon Steel Alloy**
Tensile Strength	75,400 (520)	120,350 (830)	130,500 (900)	150,800 (1040)	176,900 (1220)
Property Class	5.8	8.8	9.8	10.9	12.9
Bolt Lead Markings					
Bolt Body Size (millimeters)	Torque (Foot Pounds)	Torque (Foot Pounds)	Torque (Foot Pounds)	Torque (Foot Pounds)	Torque (Foot Pounds)
M4	N/A	2	2.5	3.5	4
M5	N/A	4.5	6	6.5	9
M6	6	8	9	11	15
M8	13	19	21	27	37
M10	33	39	42	53	73
M12	60	67	73	92	127
M14	95	107	116	148	203
M16	150	167	181	230	316
M20	300	325	352	449	617
M24	525	562	609	775	1066
M30	1075	1117	1210	1540	2188

Bolt Size (dia. in millimeters)	**Wrench Size (millimeters)**
6	10
7	11
8	13
10	17
12	19
14	22
16	24

FASTENERS
UNIT IV-A

ASSIGNMENT SHEET #1 — MATCH THE WRENCH WITH THE CORRECT SIZE BOLT (STANDARD)

NAME ______________________________________ SCORE ____________

Directions: Use Handout #1 and match the wrenches on the right with the correct bolt size.

Bolt size (dia.)		Wrench size
_____a.	1/4"	1. 1 1/2"
_____b.	5/16"	2. 3/4"
_____c.	3/8"	3. 13/16 or 7/8"
_____d.	7/16"	4. 1 1/8"
_____e.	1/2"	5. 5/8 or 11/16"
_____f.	9/16"	6. 9/16"
_____g.	5/8"	7. 1/2"
_____h.	11/16"	8. 1 1/4"
_____i.	3/4"	9. 7/16"
_____j.	7/8"	10. 1 or 1 1/16"
_____k.	1"	11. 15/16"

FASTENERS
UNIT IV-A

ASSIGNMENT SHEET #2 — MATCH THE WRENCH WITH THE CORRECT SIZE BOLT (STANDARD)

NAME ______________________________ SCORE ____________

Directions: Without the use of Handout #1, match the wrenches on the right with the correct bolt size.

Bolt size (dia.)		Wrench size
______a.	1/2"	1. 7/16"
______b.	9/16"	2. 1/2"
______c.	7/16"	3. 9/16"
______d.	7/8"	4. 5/8 or 11/16"
______e.	3/8"	5. 3/4"
______f.	11/16"	6. 13/16 or 7/8"
______g.	5/16"	7. 15/16"
______h.	1"	8. 1 or 1/16"
______i.	1/4"	9. 1 1/8"
______j.	5/8"	10. 1 1/4"
______k.	3/4"	11. 1 1/2"

FASTENERS
UNIT IV-A

ASSIGNMENT SHEET #3 — MEASURE BOLT AND THREADS (STANDARD)

NAME ________________________ SCORE ____________

Directions: Have your instructor give you a standard bolt and measure the length, bolt diameter, threads per inch, and give the grade and torque specifications for that bolt.

Your measurements:

a. Length ____________

b. Bolt diameter ____________

c. Threads per inch ____________

d. Grade of bolt ____________

e. Torque specification ____________

Hand in complete assignment to your instructor.

FASTENERS
UNIT IV-A

ASSIGNMENT SHEET #4 — MATCH THE WRENCH WITH THE CORRECT SIZE BOLT (METRIC)

NAME ______________________________________ SCORE ____________

Directions: Use Handout #2 and match the wrenches on the right with the correct bolt size.

Metric Bolt size (dia.)		Metric Wrench size
______a.	6	1. 22
______b.	7	2. 17
______c.	8	3. 24
______d.	10	4. 10
______e.	12	5. 13
______f.	14	6. 19
______g.	16	7. 11

FASTENERS
UNIT IV-A

ASSIGNMENT SHEET #5 — MATCH THE WRENCH WITH THE CORRECT SIZE BOLT (METRIC)

NAME ____ SCORE ____________

Directions: Without the use of Handout #2, match the wrenches on the right with the correct bolt size.

Metric Bolt size (dia.)		Metric Wrench size
______a.	12	1. 10
______b.	8	2. 11
______c.	16	3. 13
______d.	7	4. 17
______e.	10	5. 19
______f.	6	6. 22
______g.	14	7. 24

FASTENERS
UNIT IV-A

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

a. 9
b. 7
c. 6
d. 5
e. 2
f. 3
g. 11
h. 10
i. 4
j. 8
k. 1

Assignment Sheet #2

a. 5
b. 6
c. 4
d. 10
e. 3
f. 8
g. 2
h. 11
i. 1
j. 7
k. 9

Assignment Sheet #3 — Evaluated to the satisfaction of the instructor

Assignment Sheet #4

a. 4
b. 7
c. 5
d. 2
e. 6
f. 1
g. 3

Assignment Sheet #5

a. 5
b. 3
c. 7
d. 2
e. 4
f. 1
g. 6

FASTENERS
UNIT IV-A

JOB SHEET #1 — DRAW A TWIST DRILL TO CORRECT CENTER, AND EXTRACT A BROKEN BOLT, STUD, OR SCREW

A. Tools and materials

1. Safety glasses
2. Electric drill, 1/2" chuck
3. Twist drill
4. Center punch
5. Screw extractors
6. Ball peen hammer
7. Lubricating oil

B. Procedure

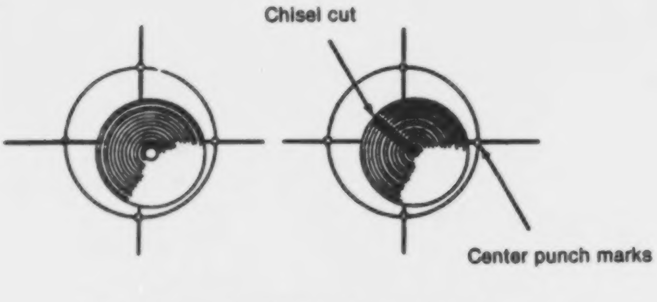
(CAUTION: Follow all shop safety procedures.)

1. Make a center punch mark close to center of broken bolt.
2. Enlarge the center punch mark slightly with drill bit at slowest speed of electric drill.

   (NOTE: Use lubricating oil on bit while drilling.)

3. Remove before whole point of bit has entered the material.
4. Check to see if hole is at center of bolt; if not, proceed as follows.
5. Make a chisel cut on side to which the drill should be drawn. (Figure 1)

FIGURE 1



How to draw the drill back to correct center

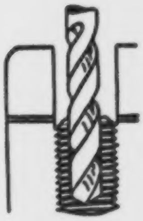
JOB SHEET #1

6. Make another punch mark for new center.

7. Repeat step 2 above.

8. After getting to center of bolt, enlarge the hole sufficiently to insert the extractor tool (Figure 2)

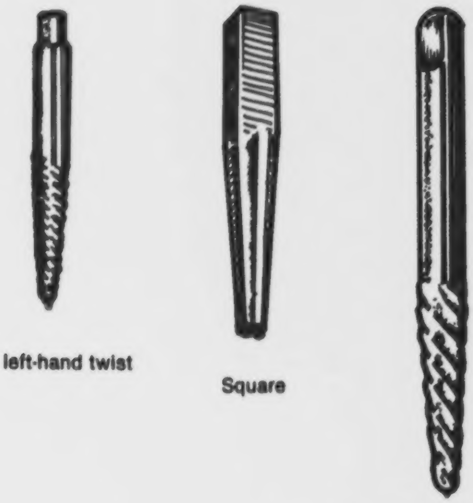
FIGURE 2



(NOTE: Try to drill the hole over the total length of the bolt to reduce stress on the threads.)

9. Select correct extractor. (Figure 3)

FIGURE 3



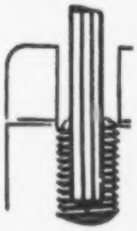
Fine left-hand twist

Square

Coarse left-hand twist

JOB SHEET #1

10. Tap the extractor lightly into the drill hole. (Figure 4)
FIGURE 4



11. Turn extractor counterclockwise to remove the bolt, stud, or screw.
(NOTE: After bolt is extracted, blow out bolt hole with compressed air.)

FASTENERS
UNIT IV-A

JOB SHEET #2 — CUT EXTERNAL THREADS

A. Tools and materials

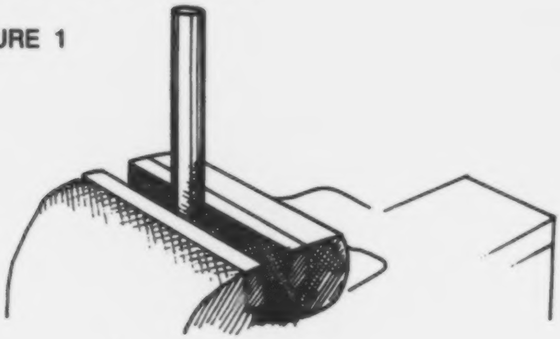
1. Die
2. Die stock (handle)
3. Vise
4. Flat tile
5. Cutting oil
6. Rod or stock to be threaded
7. Shop towel

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Place rod on vise. (Figure 1)

FIGURE 1



2. Chamfer end of rod with file. (To chamfer means to form an end that is cut away at an angle.)

3. Lubricate end of rod with cutting oil.

4. Place die in die stock and secure.

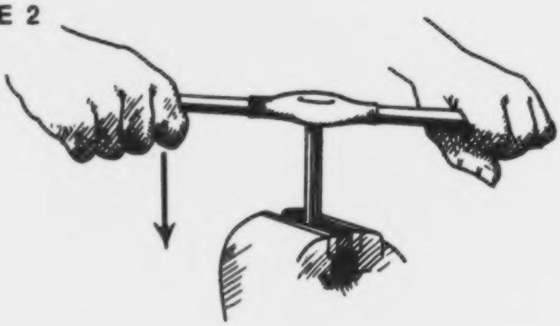
JOB SHEET #2

5. Place die on top of rod with tapered side facing down.

6. Start die straight on the rod.

7. Press down evenly and turn the die. (Figure 2)

FIGURE 2



8. Apply a few drops of cutting oil while turning the die.

9. Check die often for squareness.

10. Turn the die one turn clockwise and then one quarter to one half of a turn counterclockwise to break the chip.

11. Continue this procedure until the desired amount of threads have been cut.

12. Remove die by turning counterclockwise.

JOB SHEET #2

13. Hold onto the die stock firmly while removing it so as not to drop it when it comes to the end of the threads.

14. Clean threads with a brush.

    (CAUTION: Do not use compressed air for cleaning.)

15. Clean tools and put them away.

FASTENERS
UNIT IV-A

JOB SHEET #3 — CUT INTERNAL THREADS

A. Tools and materials

1. Tap
2. Tap wrench
3. Drill motor
4. Tap drill
5. Vise
6. Cutting oil
7. Stock to be drilled and threaded

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Place workpiece in vise.
2. Drill hole to proper size.

JOB SHEET #3

3. Use the charts below to select the proper tap drill.

   (NOTE: On some taps the size of drill bit required will be stamped on the shank.)

Coarse Thread Dimensions

Unified and American National Coarse Series, UNC, NC

Size of Thread and Threads Per Inch	Major Diameter in Inches	Pitch Diameter in Inches	Minor Diameter of External Threads in Inches	Commercial Tap Drill for About 75% Thread	Decimal Equivalent of Tap Drill in Inches
5 x 40	0.1250	0.1088	0.0943	No. 38	0.1015
6 x 32	0.1380	0.1177	0.0997	No. 36	0.1065
8 x 32	0.1640	0.1437	0.1257	No. 29	0.1360
10 x 24	0.1900	0.1629	0.1389	No. 25	0.1495
12 x 24	0.2160	0.1889	0.1649	No. 16	0.1770
1/4 x 20	0.2500	0.2175	0.1887	No. 7	0.2010
5/16 x 18	0.3125	0.2764	0.2443	F	0.2570
3/8 x 16	0.3750	0.3344	0.2983	5/16	0.3125
7/16 x 14	0.4375	0.3911	0.3499	U	0.3680
1/2 x 13	0.5000	0.4500	0.4056	27/64	0.4219
9/16 x 12	0.5625	0.5084	0.4603	31/64	0.4844
5/8 x 11	0.6250	0.5660	0.5135	17/32	0.5312
3/4 x 10	0.7500	0.6850	0.6273	21/32	0.6562
7/8 x 9	0.8750	0.8028	0.7387	49/64	0.7656
1 x 8	1.0000	0.9188	0.8466	7/8	0.8750

Fine Thread Dimensions

Unified and American National Fine Series, UNF, NF

Size of Thread and Threads Per Inch	Major Diameter in Inches	Pitch Diameter in Inches	Minor Diameter of External Threads in Inches	Commercial Tap Drill for About 75% Thread	Decimal Equivalent of Tap Drill in Inches
5 x 44	0.1250	0.1102	0.0971	No. 37	0.1040
6 x 40	0.1380	0.1218	0.1073	No. 33	0.1130
8 x 36	0.1640	0.1460	0.1299	No. 29	0.1360
10 x 32	0.1900	0.1697	0.1517	No. 21	0.1590
12 x 28	0.2160	0.1928	0.1722	No. 14	0.1820
1/4 x 28	0.2500	0.2268	0.2062	No. 3	0.2130
5/16 x 24	0.3125	0.2854	0.2614	I	0.2720
3/8 x 24	0.3750	0.3479	0.3239	Q	0.3320
7/16 x 20	0.4375	0.4050	0.3762	25/64	0.3906
1/2 x 20	0.5000	0.4675	0.4387	29/64	0.4531
9/16 x 18	0.5625	0.5264	0.4943	33/64	0.5156
5/8 x 18	0.6250	0.5889	0.5568	37/64	0.5781
3/4 x 16	0.7500	0.7094	0.6733	11/16	0.6875
7/8 x 14	0.8750	0.8286	0.7874	13/16	0.8125
1 x 14	1.0000	0.9536	0.8978	15/16	0.9375

4. Place tap in tap wrench.

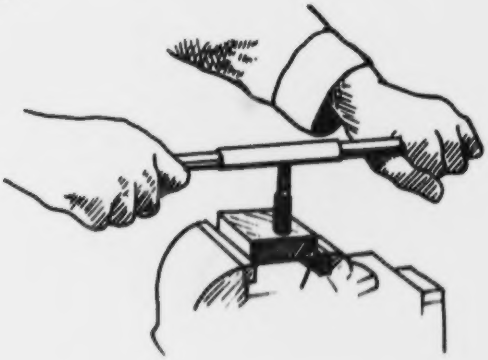
5. Place tap in hole keeping the tap as straight as possible.

6. Apply cutting oil to tap.

JOB SHEET #3

7. Press down on tap wrench with equal pressure on both sides. (Figure 1)

FIGURE 1



8. Make two complete turns with tap.

9. Check to see that the tap is straight.

10. If tap is not straight, remove it and start again.

    (NOTE: A slight amount of pressure will be required to get the tap to start straight.)

11. Tap the hole by turning the tap wrench clockwise one half of a turn then counterclockwise one quarter of a turn.

12. After the hole is tapped, remove the tap by turning the wrench counterclockwise.

    (NOTE: Hold on to the tap wrench to prevent it from falling on the floor.)

13. Clean tools and put away.

    Obtain instructor's initials here ____________.

FASTENERS
UNIT IV-A

PRACTICAL TEST
JOB SHEET #1 — DRAW A TWIST DRILL TO CORRECT CENTER, AND EXTRACT A BROKEN BOLT, STUD, OR SCREW

STUDENT'S NAME ________________________ DATE __________

EVALUATOR'S NAME ________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Followed safety procedures.	______	______
3. Punched center of bolt.	______	______
4. Used correct drill speed.	______	______
5. Rechecked for center.	______	______
6. Drew back to center.	______	______
7. Drilled bolt deep enough.	______	______
8. Used correct screw extractor.	______	______
9. Extracted screw correctly.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Bolt was extracted with no damage to the bolt hole.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

FASTENERS
UNIT IV-A

PRACTICAL TEST
JOB SHEET #2 — CUT EXTERNAL THREADS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Chamfered end of rod.	______	______
4. Lubricated with cutting oil.	______	______
5. Started die straight.	______	______
6. Checked die for squareness.	______	______
7. Cut thread to desired length.	______	______
8. Removed die.	______	______
9. Cleaned threads.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Rod is properly threaded and straight.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

FASTENERS
UNIT IV-A

PRACTICAL TEST
JOB SHEET #3 — CUT INTERNAL THREADS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety procedures.	______	______
3. Drilled holes proper size.	______	______
4. Selected correct tap.	______	______
5. Started tap correctly.	______	______
6. Checked tap for straightness.	______	______
7. Removed tap correctly.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Threads in bore are straight and clean.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

FASTENERS
UNIT IV-A

NAME ____________________ SCORE ____________________

TEST

1. Match the terms related to fasteners with the correct definitions.

_____a. Metal rod or pin that has a head at one end, a screw thread at the other end, and is secured by a nut; used for fastening objects together

_____b. An externally threaded fastener which must be torqued by its head into a tapped hole

_____c. Tool for forming an internal screw thread

_____d. Device used to secure or hold together separate items

_____e. Society of Automotive Engineers

_____f. Pointed and headed cylindrical fastener that is threaded and designed for insertion into material by rotating

_____g. Steel rod with threads on both ends, to be screwed permanently into a fixed part at one end and receive a nut on the exposed end

_____h. Internally threaded screw cutting tool; used for forming external screw threads

1. Bolt
2. Cap screw
3. Die
4. Fastener
5. SAE
6. Screw
7. Stud
8. Tap

2. Select qualities of satisfactory fasteners by placing an "X" next to the quality.

_____a. Easy to remove

_____b. Must be used with two washers

_____c. Strength

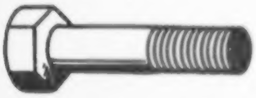
_____d. Temperature resistant

_____e. Threaded on both ends

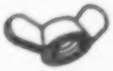
_____f. Reusability

TEST

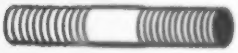
3. Identify the typical fasteners.



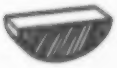
a. ____________________



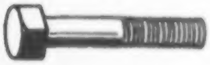
b. ____________________



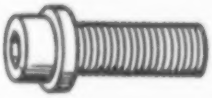
c. ____________________



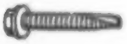
d. ____________________



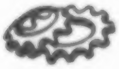
e. ____________________



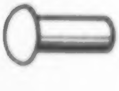
f. ____________________



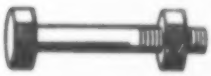
g. ____________________



h. ____________________

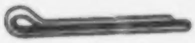


i. ____________________

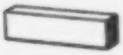


j. ____________________

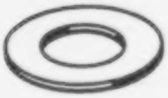
TEST



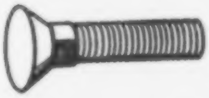
k. ______________________________



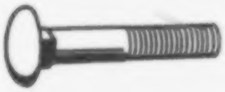
l. ______________________________



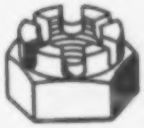
m. ______________________________



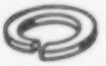
n. ______________________________



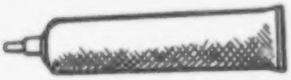
o. ______________________________



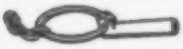
p. ______________________________



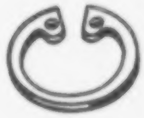
q. ______________________________



r. ______________________________

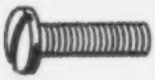


s. ______________________________

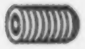


t. ______________________________

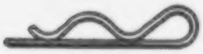
TEST



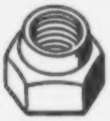
u. ______________________



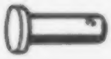
v. ______________________



w. ______________________

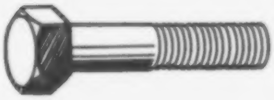


x. ______________________

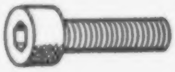


y. ______________________

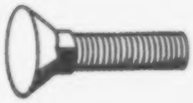
4. Identify the typical bolt head styles.



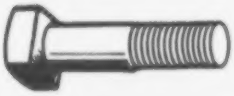
a. ______________________



b. ______________________

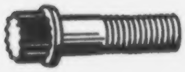


c. ______________________

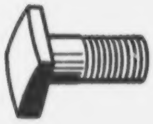


d. ______________________

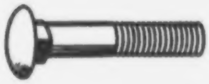
TEST



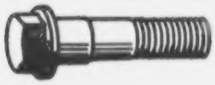
e. ______________________________



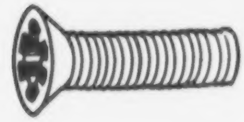
f. ______________________________



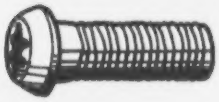
g. ______________________________



h. ______________________________

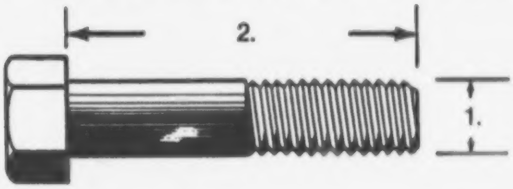


i. ______________________________



j. ______________________________

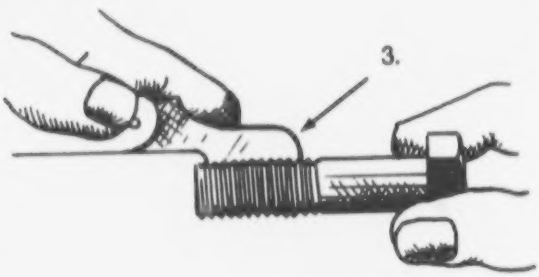
5. Identify bolt and thread measuring terms with the correct location.



____a. Bolt length

____b. Measuring thread per inch

____c. Bolt size



TEST

6. Select true statements concerning SAE grade and metric bolts and nuts by placing an "X" next to the statement(s) that are true.

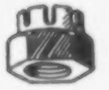
   _____a. SAE grade and metric bolts are identified by markings on the heads of the bolt.

   _____b. Metric bolts use slashes for identification.

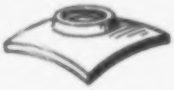
   _____c. SAE grade bolts use numbers for identification which correspond to bolt strength; increasing numbers represent increasing strength.

   _____d. Nuts are also graded so they may be mated with the same grade of fastener.

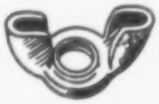
7. Identify the typical nuts.



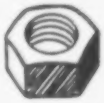
a. ______________________________



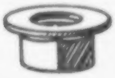
b. ______________________________



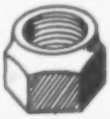
c. ______________________________



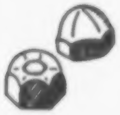
d. ______________________________



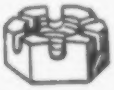
e. ______________________________



f. ______________________________

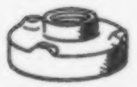


g. ______________________________

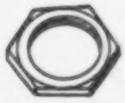


h. ______________________________

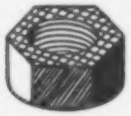
TEST



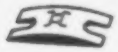
i. ____________________



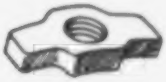
j. ____________________



k. ____________________

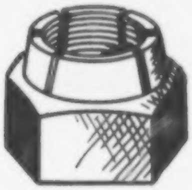


l. ____________________

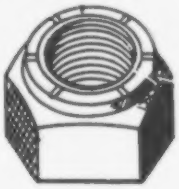


m. ____________________

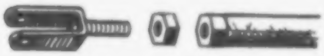
8. Identify the special purpose nuts with locking or self-locking features.



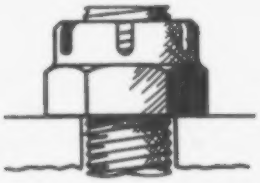
a. ____________________



b. ____________________

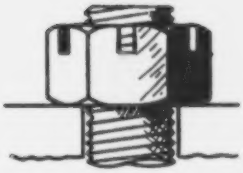


c. ____________________

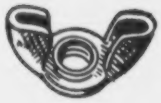


d. ____________________

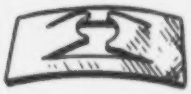
TEST



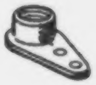
e. ____________________



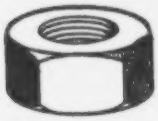
f. ____________________



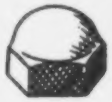
g. ____________________



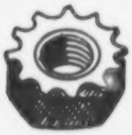
h. ____________________



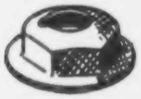
i. ____________________



j. ____________________



k. ____________________



l. ____________________

9. Select methods used to remove a seized nut by placing an "X" next to the method(s).

_____a. Hacksaw

_____b. Chisel

_____c. Acetylene torch

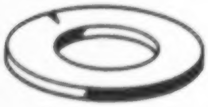
_____d. Hot water

_____e. Screwdriver

_____f. Penetrating oil

TEST

10. Identify types of washers.



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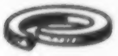

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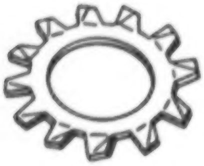

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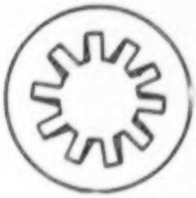

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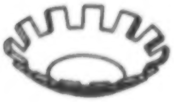

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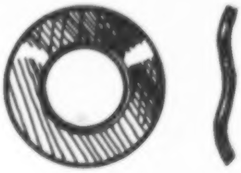

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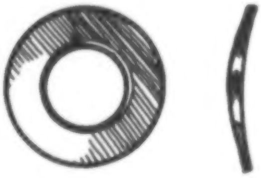


g. ______________________________

11. Select tools used to restore bolt threads by placing an "X" next to the tool(s).

______a. Rethreading tap

______b. Rethreading die

______c. Rethreading tool

______d. Die stock

TEST

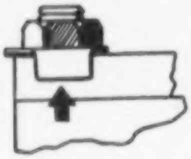
12. Select tools used to restore internal threads by placing an "X" beside the tool(s).

______a. Threading die

______b. Chisel

______c. Hand tap

13. Identify four devices for locking nuts or bolts.



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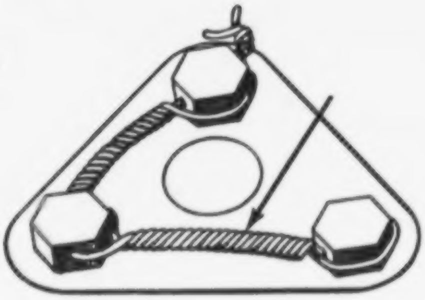

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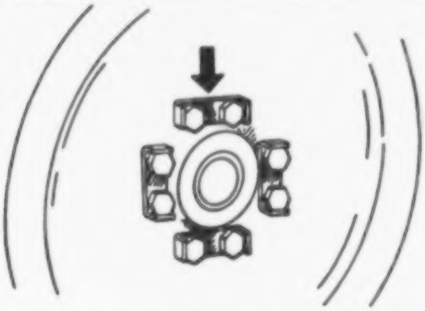

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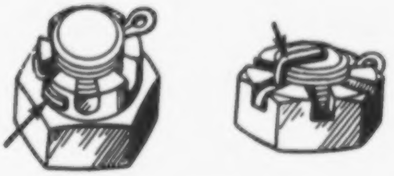
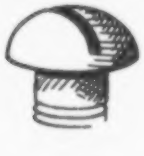


d. ______________________________

14. Identify the types of machine screw head designs.



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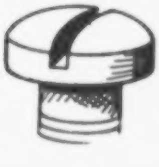

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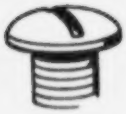

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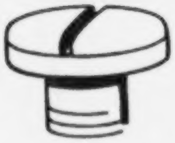

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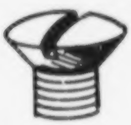
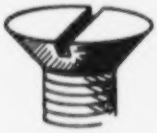


e. ______________________________



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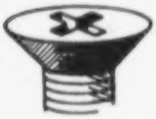
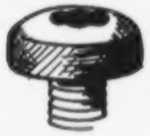
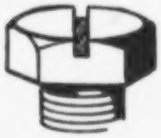


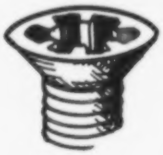
g. ______________________________



h. ______________________________

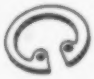


i. ______________________________

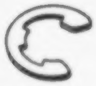


j. ______________________________

15. Identify four types of snap rings.

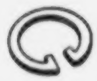


a. ______________________________



b. ______________________________

TEST



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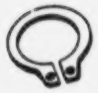


d. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

16. Match wrench with the correct size bolt (standard). (Assignment Sheet #1)

17. Match wrench with the correct size bolt (standard). (Assignment Sheet #2)

18. Measure bolt and threads. (Assignment Sheet #3)

19. Match wrench with the correct size bolt (metric). (Assignment Sheet #4)

20. Match wrench with the correct size bolt (metric). (Assignment Sheet #5)

21. Demonstrate the ability to:

    a. Draw a twist drill to correct center, and extract a broken bolt, stud, or screw. (Job Sheet #1)

    b. Cut external threads. (Job Sheet #2)

    c. Cut internal threads. (Job Sheet #3)

FASTENERS
UNIT IV-A

ANSWERS TO TEST

1.
    - a. 1
    - b. 2
    - c. 8
    - d. 4
    - e. 5
    - f. 6
    - g. 7
    - h. 3
2. a, c, d, f
3.
    - a. Hex head bolt
    - b. Wing nut
    - c. Stud
    - d. Woodruff key
    - e. Cap screw
    - f. Socket head bolt
    - g. Tapping screw
    - h. Tooth lock washer
    - i. Rivet
    - j. Bolt and nut
    - k. Cotter pin
    - l. Square key
    - m. Flat washer
    - n. Plow bolt
    - o. Carriage bolt
    - p. Castle nut
    - q. Lock washer
    - r. Adhesive
    - s. Lock pin
    - t. Snap ring
    - u. Machine screw
    - v. Set screw
    - w. Spring lock pin
    - x. Locking nut
    - y. Clevis pin
4.
    - a. Hex head bolt
    - b. Hex socket head bolt
    - c. Plow bolt
    - d. Square head cap screw
    - e. 12-point head bolt
    - f. Askew head bolt
    - g. Carriage bolt
    - h. Hex flange screw
    - i. Torx
    - j. Spline
5.
    - a. 2
    - b. 3
    - c. 1

ANSWERS TO TEST

6. a, d

7. a. Castle
   b. Spring
   c. Wing
   d. Hex
   e. Flanged
   f. Lock
   g. Acorn
   h. Slotted
   i. Weld
   j. Panel
   k. Serrated
   l. Single thread
   m. Specialty

8. a. Prevailing torque lock nut
   b. Plastic insert lock nut
   c. Jam nut
   d. Castle nut
   e. Slotted nut
   f. Wing nut
   g. Speed nut
   h. Anchor nut
   i. Chamfered nut
   j. Cap nut
   k. Flange-lock nut
   l. Pal nut

9. a, b, c, f

10. a. Flat washer
    b. Lock washer
    c. External toothed lock washer
    d. Internal toothed lock washer
    e. Countersunk external toothed washer
    f. Wave type washer
    g. Spring washer

11. b, c

12. c

13. a. Lock ears
    b. Lock wire
    c. Flat metal locks
    d. Cotter pins

ANSWERS TO TEST

14. a. Round
    b. Fillister
    c. Truss
    d. Pan
    e. Oval
    f. Flat
    g. Cross recessed or phillips
    h. Clutch
    i. Hex slotted
    j. Torx

15. a. Internal hole
    b. External "E"
    c. Internal prong
    d. External hole

16.-20. Evaluated to the satisfaction of the instructor

21. Performance skills evaluated to the satisfaction of the instructor

BEARINGS
UNIT V-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to name types of bearings and their functions. The student should also be able to list factors influencing the distribution of lubricant to the bearings, list causes of bearing failure, and demonstrate correct procedures for removal and installation of plain and anti-friction bearings. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to bearings with the correct definitions.
2. Select true statements concerning the functions of bearings.
3. Name two basic types of bearings.
4. Distinguish between axial and radial load forces on bearings.
5. Match types of bearings with the advantages and disadvantages of each type.
6. Match illustrations of plain bearings with the correct names.
7. List materials from which bearings may be constructed.
8. List factors influencing the distribution of lubricant to the bearings.
9. Identify common methods of lubricating bearings.
10. List causes of bearing failure in plain bearings.

OBJECTIVE SHEET

11. Select true statements concerning reasons for bearing crush.

12. Identify types of anti-friction bearings.

13. List conditions that determine the load carrying capacity of anti-friction bearings.

14. Match names of ball bearing races with ball bearings.

15. Match names of ball bearings with the design.

16. Match names with the correct type of roller bearing.

17. Identify types of needle bearings.

18. Select true statements concerning mountings for anti-friction bearings.

19. Select bearing maintenance tips.

20. Demonstrate the ability to:

    a. Remove and install camshaft bearings (friction). (Job Sheet #1)

    b. Remove and install an anti-friction bearing. (Job Sheet #2)

    c. Check Detroit Diesel idler gear bearing pre-load, spring scale method. (Job Sheet #3)

    d. Clean and lubricate (pack) an anti-friction bearing. (Job Sheet #4)

BEARINGS
UNIT V-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

  1. Discuss typical adjusting (preloading) devices for tapered roller bearings to include slotted hex nut and cotter pin, lock nuts and torqued washer, shims, and threaded cup follower.
  2. Have students show the different layers in a split bearing.
  3. Identify different types of bearings from a display.
  4. Show film on application and/or installation of bearings.
  5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Shop Manual.* Cummins Engine Company, Inc., Columbus, IN: 1981.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

C. *Fundamentals of Service: Bearings and Seals.* 3rd ed. Moline, IL: Deere and Company, 1980.

D. *Service Manual: Detroit Diesel Engine Series 92.* Detroit, MI: Detroit Diesel Allison, 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. *Diesel Mechanics, 2nd edition*
Gregg/McGraw-Hill
Box 996
Norcross, GA 30091
(404) 449-1836

2. *Oil and Your Engine*
Caterpillar Tractor Company
Building JJ Service Training
600 W. Washington Street
East Peoria, IL 61630

B. Safety films

1. *Bearing.* color, 19 min.
Lucerne Films, Inc.
211 Fig Street
Fairhope, OH 36532
1 800 633-1858

2. *Bearing and Seals* 125 slides
John Deere Distribution Service Center
Service Training, Dept. 333
1400 3rd Avenue
Moline, IL 61265
(309) 757-5903

3. *Main and Connecting Rod Bearings — Worn Parts Evaluation.* 65 slides and script
Caterpillar Tractor Co.
Building JJ Service Training
600 West Washington Street
East Peoria, IL 61630

BEARINGS
UNIT V-A

INFORMATION SHEET

I. **Terms and definitions**

- A. Anti-friction bearing — Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces
- B. Axial load — A force directed endways or horizontal to the shaft
- C. Babbit — A soft metal used to line bearings (an alloy of lead, tin, antimony, and other metals)
- D. Bearing crush — The distance that each half of the bearing extends beyond the bearing seat bore, usually one or two thousandths of an inch
- E. Friction — Resistance to motion between two bodies in contact
- F. Plain bearing — Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

  (NOTE: Plain bearings are also called bushings.)
- G. Plastigage® — Plastic thread which "crushes" to the exact clearance when measuring bearing clearance
- H. Preloading — Adjustment of anti-friction bearing after being secured in the mounting
- I. Races — Two hardened steel rings
- J. Radial load — A force directed sideways or perpendicular to the shaft

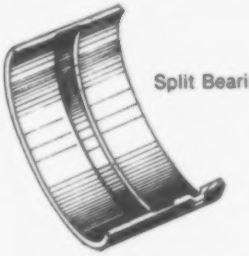
II. **Functions of bearings**

- A. Support the moving part
- B. Reduce friction
- C. Reduce wear
- D. Provide a replaceable wear surface

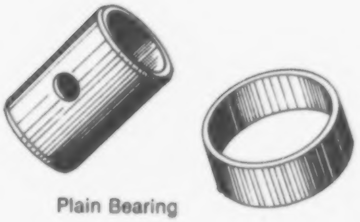
INFORMATION SHEET

III. Basic types of bearings

A. Friction (plain bearing)

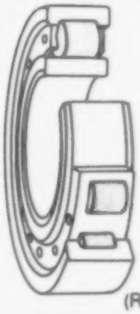


Split Bearing

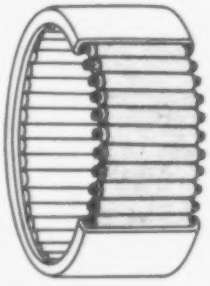


Plain Bearing

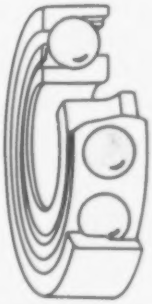
B. Anti-friction bearing



Roller Bearing



Needle Bearing



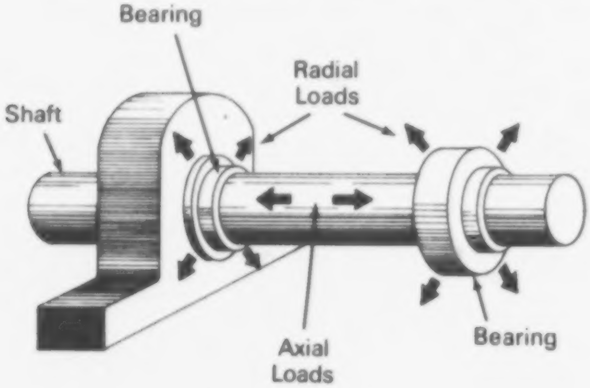
Ball Bearing

(Reproduced by permission of Deere & Company, © 1987 Deere & Company. All rights reserved.)

IV. Load forces on bearings

A. Axial load forces are those forces directed endways or horizontal to the shaft.

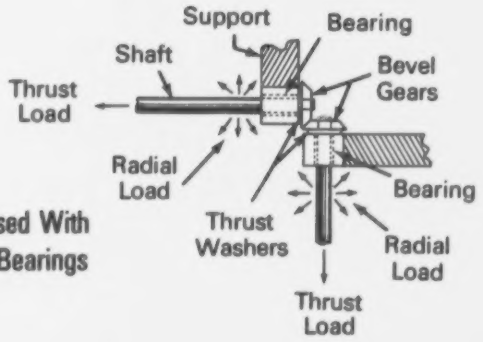
(NOTE: Thrust bearings are used to support the endways force.)



Load Forces Acting On Bearings

INFORMATION SHEET

B. Radial load forces are those forces directed sideways or perpendicular to the shaft.


Support
Bearing
Shaft
Bevel Gears
Thrust Load
Radial Load
Bearing
Thrust Washers
Radial Load
Thrust Load

Thrust Washers Used With Radial-Load-Type Bearings

V. Advantages and disadvantages of plain bearings and anti-friction bearings

A. Plain bearings (bushings)

  1. Advantages

    a. Require little space

    b. Low in cost

    c. Quiet operation

    d. Rigid construction

  2. Disadvantages

    a. High friction operation

    b. Require more frequent lubrication because they cannot be packed

B. Anti-friction bearings

  1. Advantages

    a. Low friction operation

    b. Can be packed to reduce frequency of lubrication

    c. More versatile, many designs

INFORMATION SHEET

2. Disadvantages

   a. Require more space

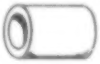
   b. Noisier operation

   c. Higher cost

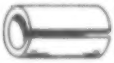
   d. Less rigidity

VI. Types of plain bearings

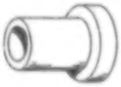
A. Solid or sleeve



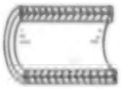
B. Split, rolled type



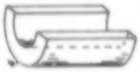
C. Thrust



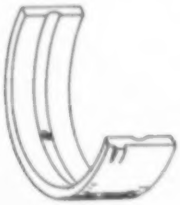
D. Split with steel back lined with bronze or babbit



E. Split, constructed of wood, plastic, or rubber

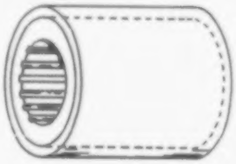


F. Split, used for engine crankshaft



INFORMATION SHEET

G. Solid with fluted rubber structure



VII. **Materials from which bearings may be constructed**

A. Cast iron

B. Soft steel

C. Hard steel

D. Copper, brass, and bronze

E. Copper, lead

F. Babbit

G. Aluminum

H. Plastic

I. Rubber

VIII. **Factors influencing the distribution of lubricant to the bearings**

A. Oil grooves

B. Bearing clearance

C. Bearing surface compatibility

(NOTE: Bearing surface compatibility is determined by viscosity of the lubricant, speed of shaft rotation, and smoothness of the mating surfaces.)

IX. **Methods of lubricating bearings** (Transparency 1)

A. Grease gun (hand or power)

B. Central grease (manifold)

(NOTE: One plunger lubricates several grease fittings.)

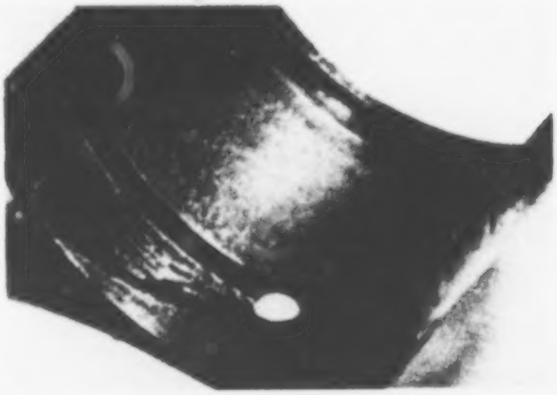
C. Circulating splash

D. Pressure feed

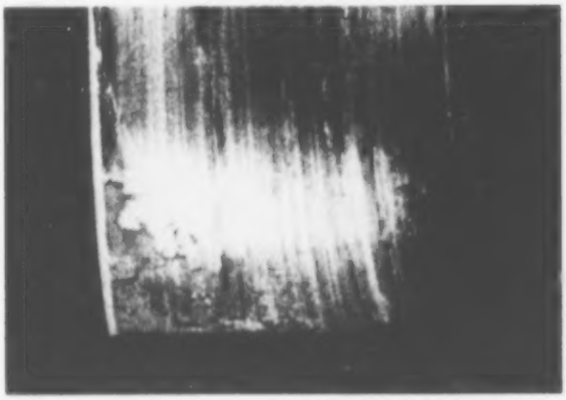
INFORMATION SHEET

X. **Causes of bearing failure in plain bearings**

A. Dirt



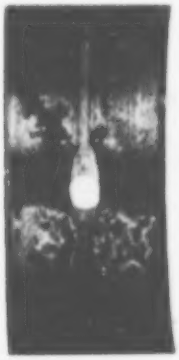
B. Lack of lubrication and improper lubrication



(Courtesy of Caterpillar, Inc.)

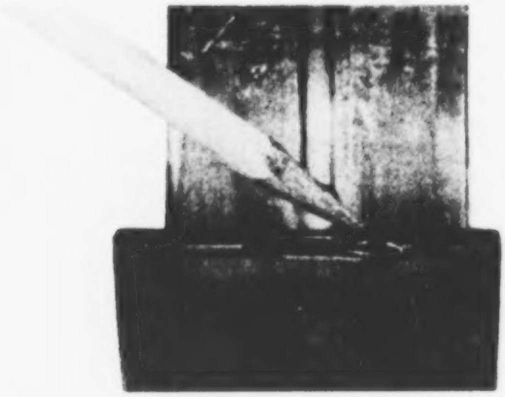
C. Improper assembly

(NOTE: Improper assembly may result in too little or too much bearing crush, improper bearing clearance, or mislocated oil hole.)

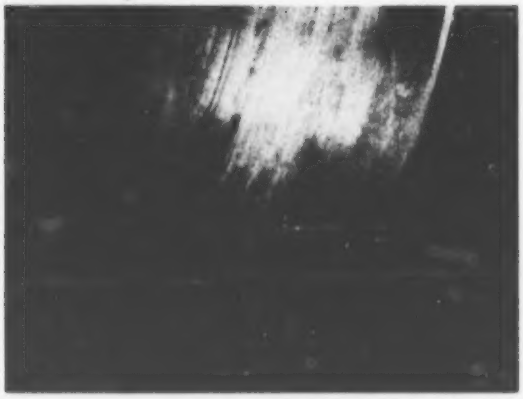


INFORMATION SHEET

D. **Misalignment**



E. **Overloading**



(Courtesy of Caterpillar, Inc.)

F. **Corrosion**

INFORMATION SHEET

XI. **Reasons for bearing crush**

A. Greater heat dissipation

B. Insert is forced to seat solidly

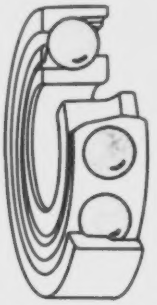
C. Insures that the bearings remain round

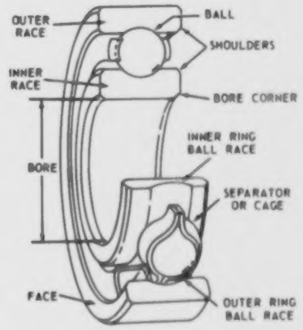
D. Avoids any possible movement of the bearing in the seat

(NOTE: The amount of crush must not be excessive (.001" or .002") or the insert will be distorted when the cap is tightened. The bearing will buckle and will result in increased friction and heat.)

XII. **Types of anti-friction bearings**

A. Ball




OUTER RACE
BALL
SHOULDERS
INNER RACE
BORE CORNER
INNER RING BALL RACE
BORE
SEPARATOR OR CAGE
FACE
OUTER RING BALL RACE

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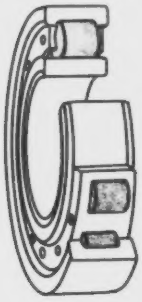
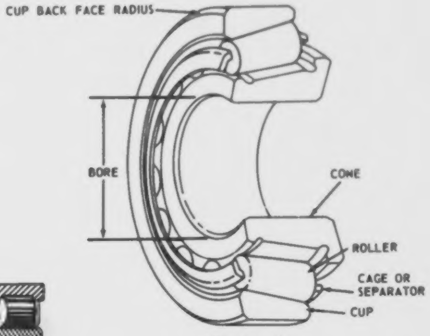
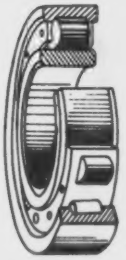
B. Roller



Straight


CUP BACK FACE RADIUS
BORE
CONE
ROLLER
CAGE OR SEPARATOR
CUP

Tapered



Self-Aligning

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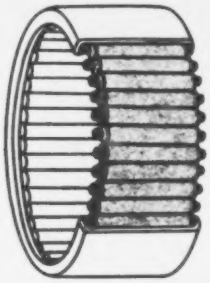
INFORMATION SHEET

C. Needle



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XIII. Conditions that determine load carrying capacity of anti-friction bearings

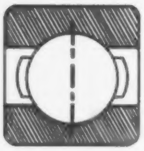
A. Size of bearing

B. Number of rolling elements

C. Type of race

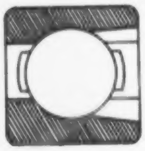
XIV. Types of ball bearing races

A. Conrad



Inner Race In Eccentric Position For Loading. Good for Both Radial and Thrust Loads.

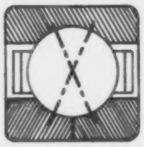
B. Full



Has a Loading Slot. Holds More Balls, Only For Radial Loads.

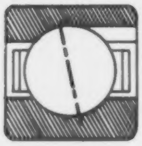
INFORMATION SHEET

C. Split race



Inner Race is Center-Cut. Good for Thrust Loads Only.

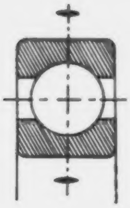
D. Angular contact



One Shoulder Of Outer Race Removed. Good For Thrust Loads — One Direction

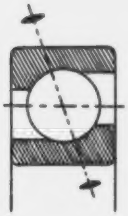
XV. **Designs of ball bearings**

A. Radial load

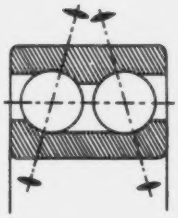


Single Row Radial

B. Radial and thrust load



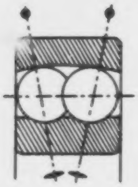
Single Row Radial-Thrust



Double Row Radial-Thrust

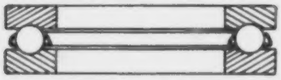
INFORMATION SHEET

C. Self-aligning, radial load

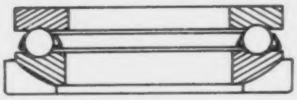


Double Row Self-Aligning Radial

D. Thrust load



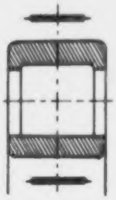
Open Face Ball Thrust
(Separable)



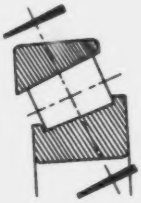
Self-Aligning Ball Thrust
(Separable)

XVI. **Types of roller bearings**

A. Radial load, straight

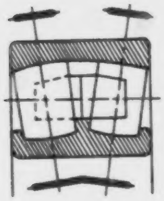


B. Radial and thrust load, tapered

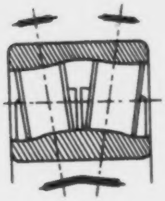


INFORMATION SHEET

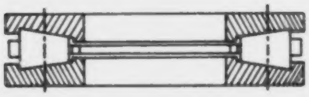
C. Self-aligning, radial and thrust load, spherical



D. Self-aligning, radial and thrust load, concave

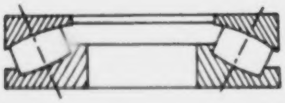


E. Thrust load



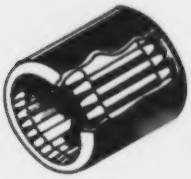
Tapered

Spherical
Self-Aligning



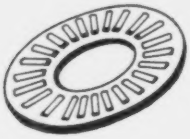
XVII. **Types of needle bearings**

A. Radial load



INFORMATION SHEET

B. Thrust load (Torington)



XVIII. **Mountings for anti-friction bearings** (Transparencies 2, 3, and 4)

A. Shape must not be distorted.

B. Rolling elements must not be bound.

C. Inner and outer races must be aligned.

(NOTE: This is not necessary with self-aligning bearings.)

D. Axis of each bearing must be aligned with the other.

(NOTE: The above condition applies when two or more bearings are mounted on the same shaft.)

E. Usually mounted with one race a press fit and the other a push fit.

(NOTE: Normally the press fit race is pressed onto or into the rotating part and the push fit onto or into the stationary part. This rule of thumb is not true in every situation. Large bearings, tremendous loads, and high speeds may require both races to be pressed into place.)

F. Seals are used to retain lubricant and exclude dirt.

XIX. **Bearing maintenance tips**

A. Work with clean approved tools, in clean surroundings.

B. Clean outside of housings before exposing bearings.

C. Handle bearings with clean, dry hands.

D. Work on a metal or metal covered bench.

E. Treat a used bearing as carefully as a new one, until the used one is proven to be defective.

F. Use clean solvents and flushing oils.

G. Lay bearings out on a clean surface.

INFORMATION SHEET

H. Protect disassembled bearings from dirt and moisture.

I. Wipe bearings, if necessary, only with clean, lint-free rags.

J. Keep bearings wrapped in oil-proof paper when not in use.

K. Thoroughly clean the inside of housings before installing bearings.

L. Install new bearings as they come from the package, without washing, if they are received in a sealed container.

M. Keep lubricants clean when applying them, and cover the containers when not in use.

N. Don't spin uncleaned or dry bearings.

O. Don't spin any bearing with compressed air.

P. Don't use the same container for both cleaning and final rinse of used bearings.

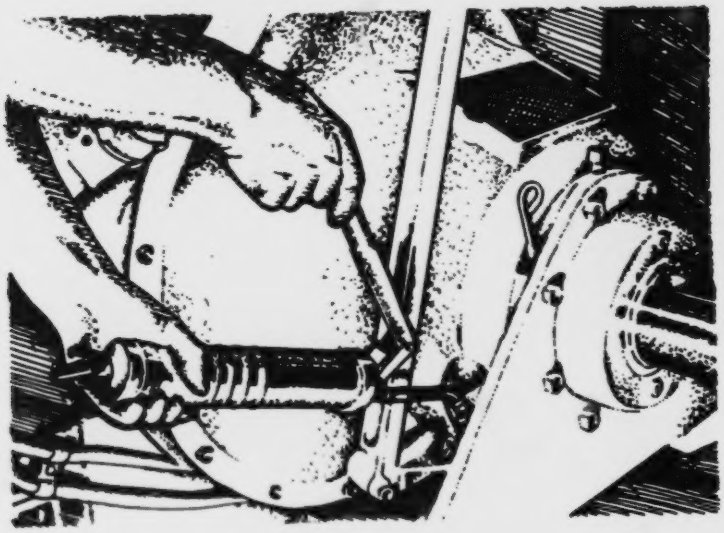
Q. Don't use gasoline as a cleaning solvent.

(CAUTION: The fumes may be injurious to health, as well as a fire hazard.)

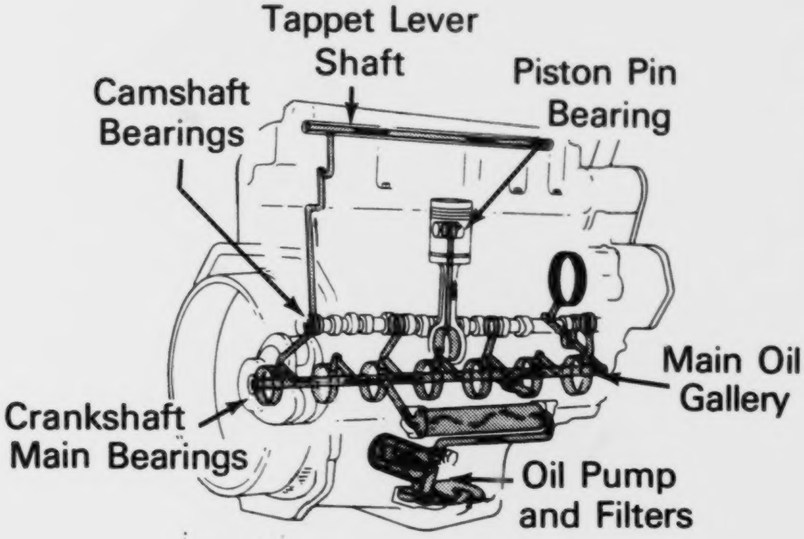
R. Don't use incorrect type or amount of lubricant.

Methods of Bearing Lubrication

Hand Lubrication

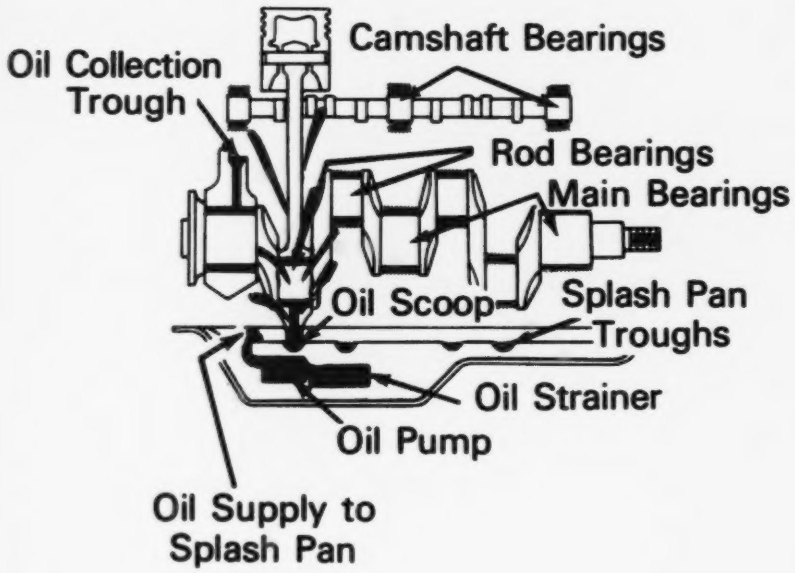


Pressure-Feed Oil System in a Typical Engine

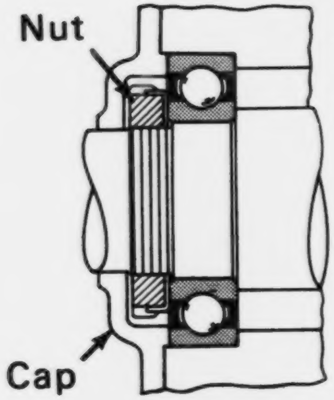

Tappet Lever Shaft
Camshaft Bearings
Piston Pin Bearing
Main Oil Gallery
Crankshaft Main Bearings
Oil Pump and Filters

Methods of Bearing Lubrication

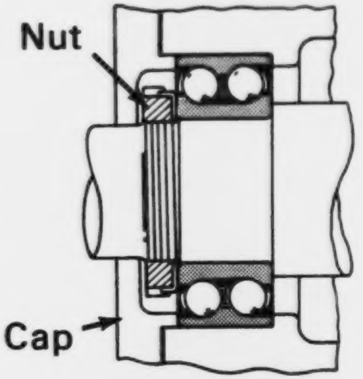
Circulating Splash System


Camshaft Bearings
Oil Collection Trough
Rod Bearings
Main Bearings
Oil Scoop
Splash Pan Troughs
Oil Strainer
Oil Pump
Oil Supply to Splash Pan

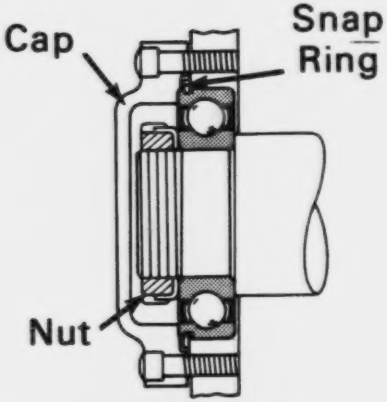
Typical Ball Bearing Mountings



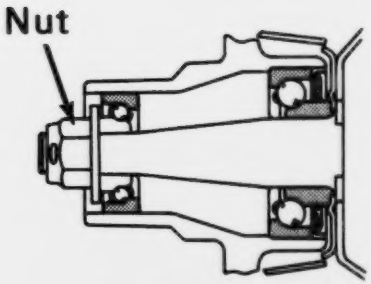
Single Row
Radial



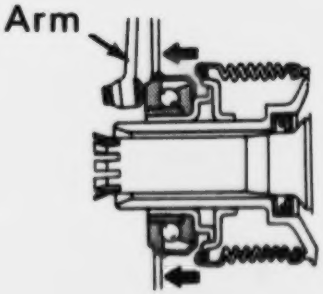
Double Row
Radial-Thrust


Cap
Snap Ring
Nut

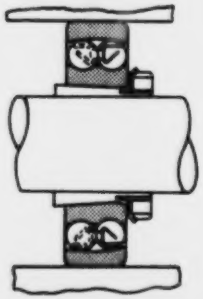
Single Row
Snap Ring



Radial-Thrust

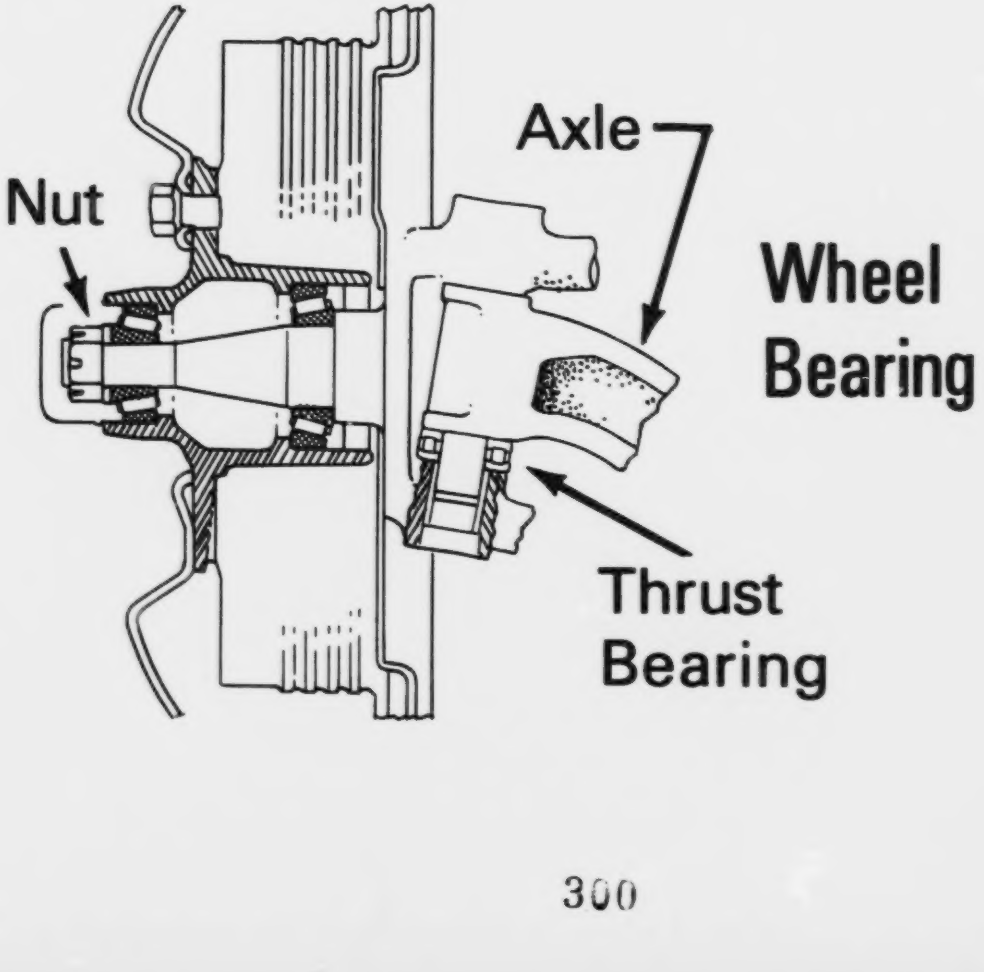


Thrust

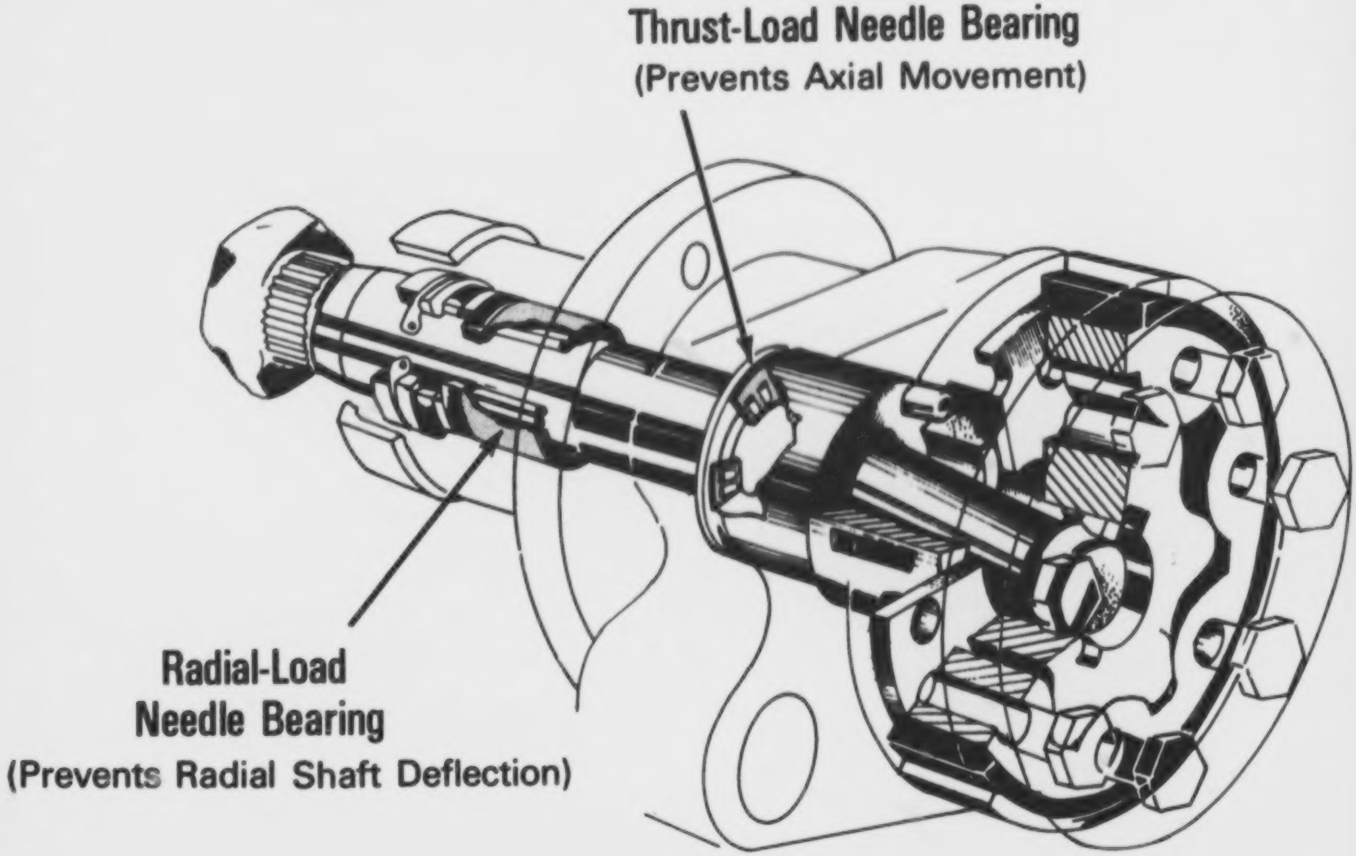


Self-Aligning

Typical Roller Bearing Mountings


Axle
Nut
Wheel Bearing
Thrust Bearing

Typical Needle Bearing Mountings


Thrust-Load Needle Bearing
(Prevents Axial Movement)
Radial-Load
Needle Bearing
(Prevents Radial Shaft Deflection)

BEARINGS
UNIT V-A

JOB SHEET #1 — REMOVE AND INSTALL CAMSHAFT BEARINGS (FRICTION)

A. Tools and materials

1. Shop safety glasses
2. Clean shop towels
3. Basic hand tools
4. Cam bearing remover and installer tool
5. Shop engine with cam bearings
6. Bristled brush

B. Procedure

(CAUTION: Follow all shop safety procedures.)

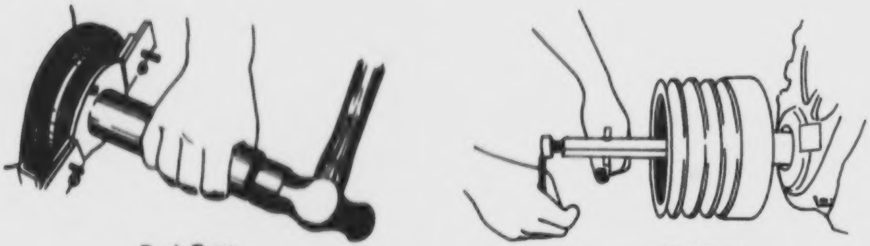
1. Place engine on blocks or engine stand with the crankshaft chamber facing up.
2. Remove camshaft bearings.

   (NOTE: Check the appropriate manual of the engine being worked on for the correct puller and installer because some pull the bearing in while others push the bearing out.)

   a. Select the correct size of puller adapter for each bearing. (Figure 1)

      (NOTE: Some engines may have cam bearings with all the same inside diameter and others may have different sizes.)

FIGURE 1



Push Type

Pull Type

JOB SHEET #1

b. Remove the front and rear bearings first; then remove the intermediate bearings.

(NOTE: Some manufacturers recommend pulling intermediate bearings first; then the front and rear.)

c. As you remove the bearings, place them in order on a clean work bench.

(NOTE: Keep the old bearing marked for correct positioning in the bore and for correct location to help install the new bearing.)

d. Clean the camshaft bearing bores.

e. Clean the oil passages in the block with a bristled brush, and blow out with compressed air.

3. Install new camshaft bearings.

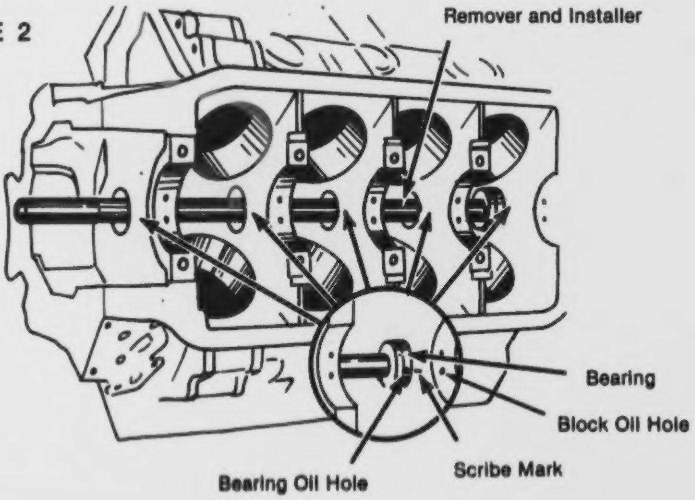
a. Place the new camshaft bearing on a clean shop towel in the order of installation.

b. Check with the service manual on procedure for installing camshaft bearing.

c. Place the new bearing on the installer adapter. (Figure 2)

(NOTE: To ease oil hole alignment, mark the adapter in line with the bearing oil hole and oil passage in blocks.)

FIGURE 2



Obtain instructor's initials here ____________ before proceeding to the next step.

JOB SHEET #1

d. Install the bearing while aligning the oil hole with the alignment mark.

e. Remove installing tool and adapter, and check oil passage in the bearing.

(NOTE: The bearing oil holes should align with the engine oil holes, and the bearing should not stick out past the block on either side of bore.)

f. Install the remaining bearings using the same procedure.

Obtain instructor's initials here ____________

BEARINGS
UNIT V-A

JOB SHEET #2 — REMOVE AND INSTALL AN ANTI-FRICTION BEARING

A. Tools and materials

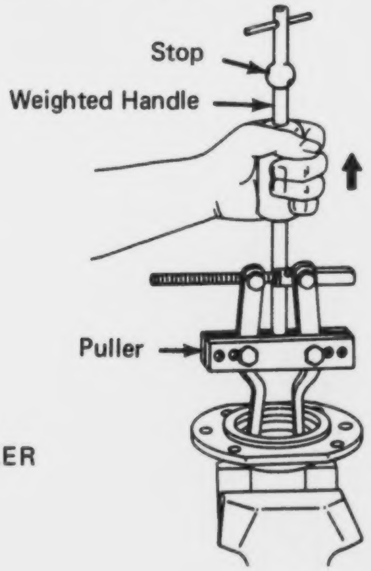
1. Safety glasses
2. Shop towels
3. Basic tool set
4. Appropriate service manual
5. Pullers
6. Press
7. Vise
8. Support blocks

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove bearing using pullers.
   a. Clean bearing housing and shaft.
   b. Study bearing mounting and determine how it can be removed using bearing pullers 1, 2, or 3 shown below.
      1) Using a slide hammer puller, slide the hammer against the stop and force bearing from housing. (Figure 1)

FIGURE 1

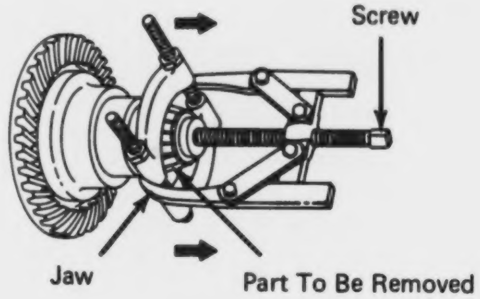


SLIDE-HAMMER
INTERNAL PULLER

JOB SHEET #2

2) Using a screw type puller, pull bearing from the shaft by force of screw turning. (Figure 2)

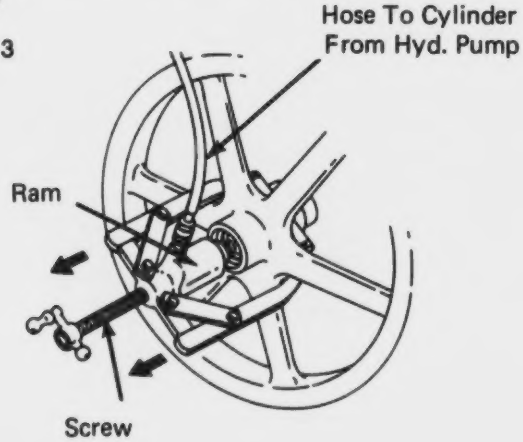
FIGURE 2


Screw
Jaw
Part To Be Removed

EXTERNAL SCREW-TYPE PULLER

3) Using a hydraulic powered puller, pull bearing from shaft by force. (Figure 3)

FIGURE 3


Hose To Cylinder
From Hyd. Pump
Ram
Screw

HYDRAULICALLY-POWERED PULLER

Obtain instructor's initials here ____________ before proceeding to next step.

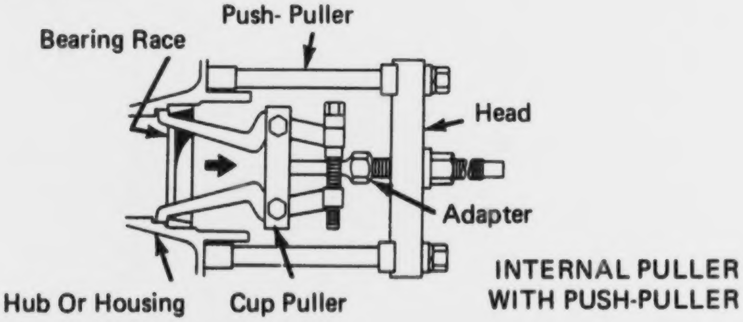
JOB SHEET #2

c. Make the correct puller application using 1, 2, or 3 below.

(NOTE: Pullers may be for either internal or external applications, depending on the need. Some pullers can be used for both jobs because they have reversible jaws with both external and internal ends.)

1) Make puller application using an internal type with push-puller. (Figure 4)

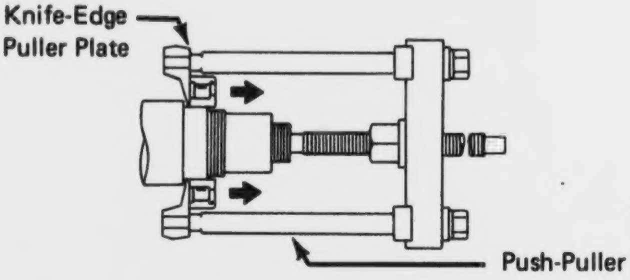
FIGURE 4


Push- Puller
Bearing Race
Head
Adapter
Hub Or Housing
Cup Puller
INTERNAL PULLER WITH PUSH-PULLER

(NOTE: The push-puller may also be used for installation. The legs of the push-puller support the head while the screw is turned, pulling the bearing cup from the housing.)

2) Make puller application using a knife-edge puller plate with push puller. (Figure 5)

FIGURE 5


Knife-Edge Puller Plate
Push-Puller

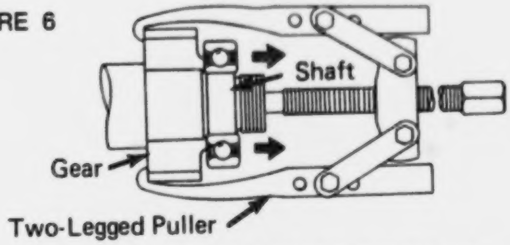
KNIFE-EDGE PULLER PLATE WITH PUSH-PULLER

(NOTE: A knife-edge puller plate is available to remove bearings where other pullers would damage the bearing. This plate is shown (Figure 5) removing a bearing from a shouldered shaft. If the regular external-type puller were used to remove this bearing, the force exerted on the outer race would damage the bearing. Notice that the knife-edge plate is used with a push-puller; the external screw type puller can also be used with the knife-edge plate.)

JOB SHEET #2

3) Make puller application using an external screw type puller. (Figure 6)

FIGURE 6


Shaft
Gear
Two-Legged Puller

EXTERNAL SCREW TYPE PULLER

(NOTE: The external screw type puller can be used to remove bearings provided there is some solid object which allows the jaws of the puller to force the bearing off.)

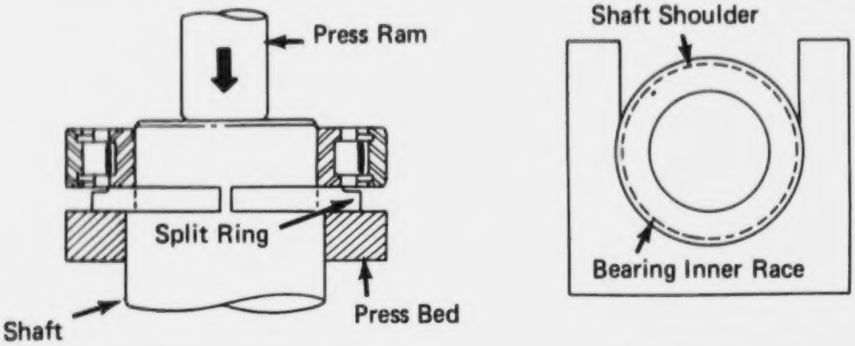
d. Force the bearing from the shaft.

Obtain instructor's initials here ____________ before proceeding to next step.

2. Remove bearing using a press. (Figure 7)

a. Support inner race with split rings or U-plates as available. (Figure 7)

FIGURE 7


Press Ram
Split Ring
Shaft
Press Bed
Shaft Shoulder
Bearing Inner Race

SPLIT RING SUPPORT

U-PLATE SUPPORT

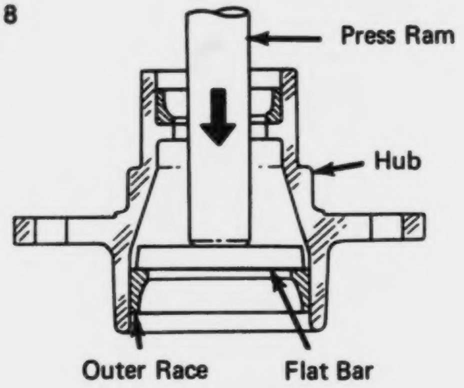
b. Press bearing from shaft.

JOB SHEET #2

c. Press bearing cup from housing using a flat bar which transmits ram pressure. (Figure 8)

(NOTE: Housing must be open from opposite side.)

FIGURE 8


Press Ram
Hub
Outer Race
Flat Bar

BEARING CUP REMOVAL

d. Press outer race from housing using a tube slightly smaller than the outer race. (Figure 9)

FIGURE 9

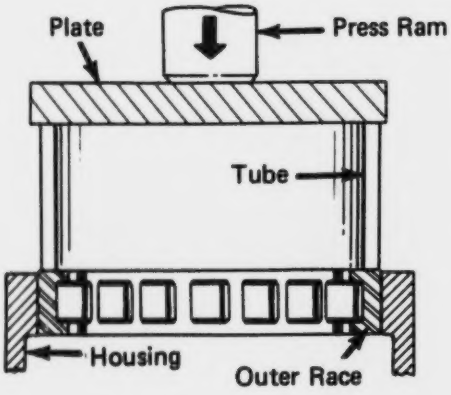


Plate
Press Ram
Tube
Housing
Outer Race

Obtain instructor's initials here ______________ before proceeding to next step.

JOB SHEET #2

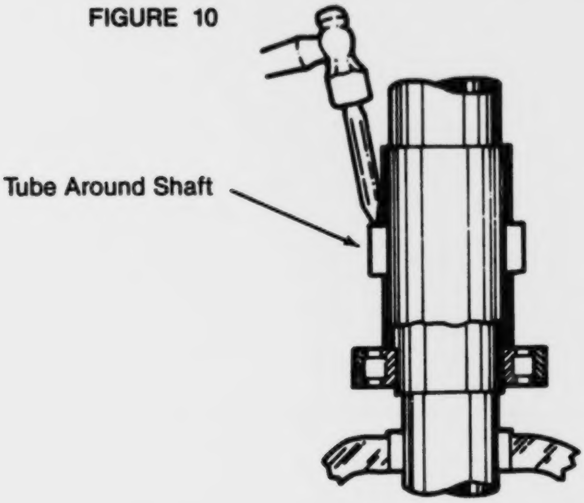
3. Remove bearing with a hammer and driver using either method below.

   a. Method #1

      1) Place tube over shaft to drive bearing from the shaft. (Figure 10)

         (NOTE: If shaft has obstructions, tube may be split and tied.)

FIGURE 10

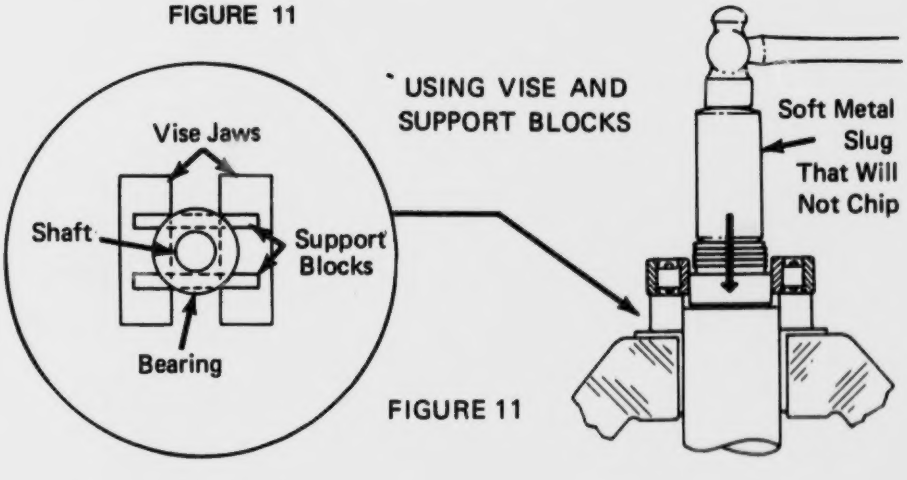

Tube Around Shaft

      2) Strike the welded lug with hammer and punch.

   b. Method #2

      1) Use support blocks, split rings, or a U-plate to support inner race of the bearing. (Figure 11)

FIGURE 11


USING VISE AND SUPPORT BLOCKS
Vise Jaws
Shaft
Support Blocks
Bearing
Soft Metal Slug That Will Not Chip
FIGURE 11

JOB SHEET #2

Obtain instructor's initials here ____________ before proceeding to next step.

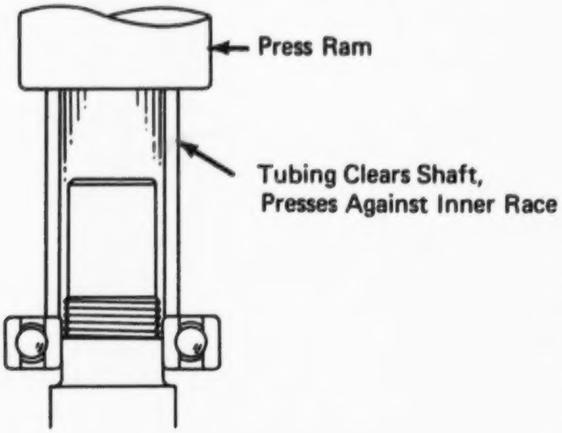
2) Drive the shaft from the bearing with a soft slug or driver.

4. Install bearings using appropriate method below.

(NOTE: The safest way to install a bearing to a shaft is to heat the bearing to 250°F. This is done in an oven, or bearing can be heated in a container of oil. Heating the bearing will expand it so that the inner race slides freely onto the shaft.)

a. Press inner race on shaft by using press method. (Figure 12)

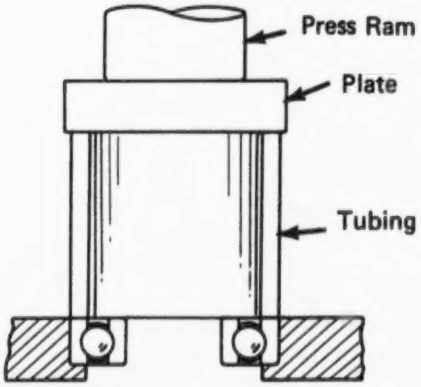
FIGURE 12


Press Ram
Tubing Clears Shaft, Presses Against Inner Race

(NOTE: No pressure is exerted on outer race.)

b. Press outer race in housing by using press method. (Figure 13)

FIGURE 13

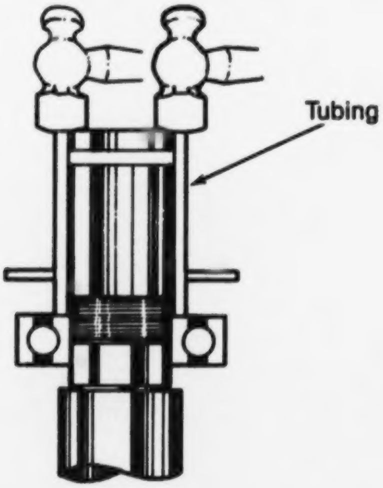

Press Ram
Plate
Tubing

(NOTE: No pressure is exerted on inner race.)

JOB SHEET #2

c. Drive inner race on shaft with hammer. (Figure 14)

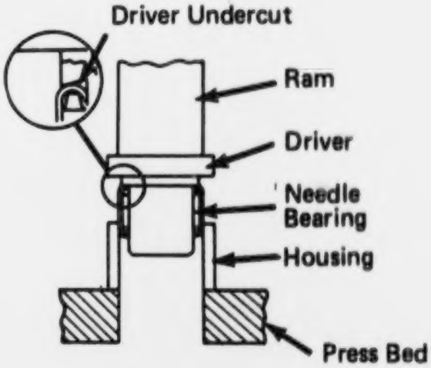
FIGURE 14



(NOTE: No pressure is exerted on outer race.)

d. Press needle bearing into housing with press. (Figure 15)

FIGURE 15


Driver Undercut
Ram
Driver
Needle Bearing
Housing
Press Bed

(NOTE: Use special undercut driver to transmit driving force to outer shell, preventing bearing shell from buckling.)

Obtain instructor's initials here ____________

BEARINGS
UNIT V-A

JOB SHEET #3 — CHECK DETROIT DIESEL IDLER GEAR BEARING PRE-LOAD, SPRING SCALE METHOD

A. Tools and materials

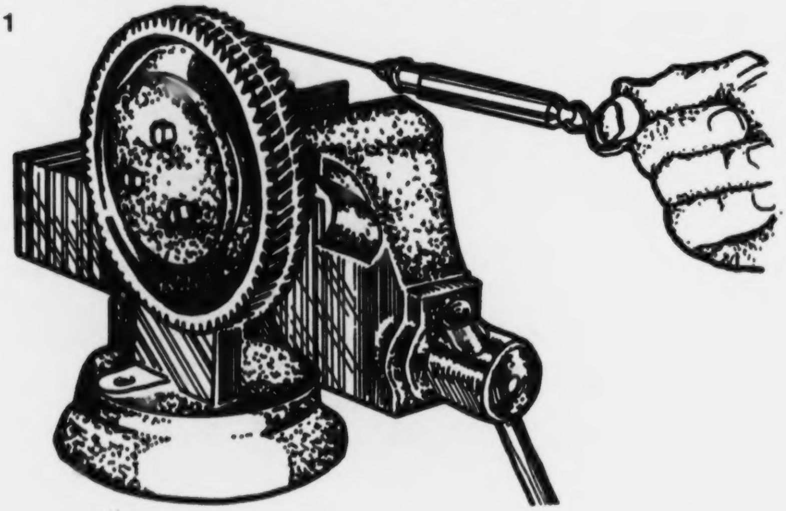
1. Safety glasses
2. Basic hand tools
3. Detroit Diesel service manual
4. Spring scale
5. String or cord
6. Shop work bench with vise
7. Detroit Diesel idler gear assembly and holding fixture

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clamp the idler gear assembly and holding fixture into a vise.
2. Tie one end of a piece of cord around a short piece of wood.
3. Place the cord between two of the gear teeth, and wrap the cord around the periphery of the gear several times.
4. Attach the other end of the cord to a spring scale. (Figure 1)

FIGURE 1



JOB SHEET #3

5. Check service manual for pre-load specification, and write service manual specification here ____________.

   Obtain instructor's initials here ____________ before proceeding to next step.

6. Maintain a straight steady pull on the cord and scale, 90° to the axis of the hub.

7. Note the pull required to start the gear rotating.

8. Make several checks to obtain an average reading.

9. Record your average reading here ____________________________________.

   (NOTE: If readings are within specification, the assembly is ready to be installed onto engine. If it is not within specification, the bearings need to be checked again and retested. If it is still not within specification, replace the bearings.)

10. Remove the spring scale and holding fixture from the bearing assembly.

BEARINGS
UNIT V-A

JOB SHEET #4 — CLEAN AND LUBRICATE (PACK) AN ANTI-FRICTION BEARING

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Basic hand tools
4. Recommended cleaning solvent
5. Recommended bearing grease
6. Bearing packer

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Place bearings in a basket and let them soak for some time in a recommended cleaning solution.
2. Agitate the basket several times after bearings have soaked for a period of time.
3. Remove and inspect the bearings one at a time.
4. Use a durable brush to loosen the dirt particles.
5. Complete the cleaning by moving the bearings back and forth in the solvent and then repeat this procedure in a clean solvent bath.
6. Use compressed air to remove any remaining particles and to remove the solvent.

   (CAUTION: Hold both races of the bearing while cleaning with compressed air. Never allow a race to spin by the force of the air; the ring may explode.)

7. Dip the bearing in light engine oil and gently rotate it a few times.
8. Place bearing on a clean shop towel to drain off excess oil.
9. Check the bearing rollers and races for discoloration, damaged races, seals, separator, balls or rollers.

   Obtain instructor's initials here ____________ before proceeding to next step.

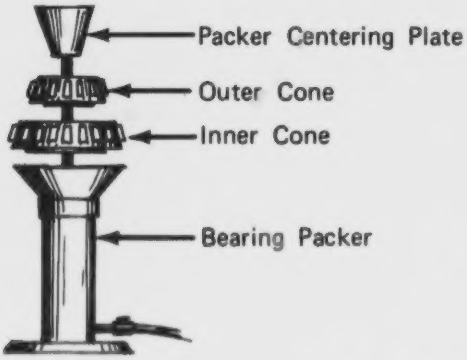
JOB SHEET #4

10. After inspection, if the bearing appears satisfactory, dip the bearing in clean oil and store in greaseproof paper until it is to be installed.

    (NOTE: Before some bearings are to be installed they have to be lubricated [packed] with grease.)

11. Place the clean bearing into the bearing packer. (Figure 1)

    FIGURE 1

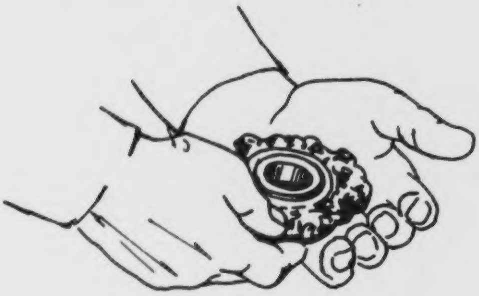


12. Unscrew the packer centering plate and install bearing.
13. Screw the packer centering plate down and center bearing.
14. Force the grease through the cones slowly enough to observe when the bearing cage is completely filled with grease.
15. Remove the cones from the packer, and cover the ends of the rollers with grease.

JOB SHEET #4

NOTE: If a bearing packer is not available, the bearing will have to be packed by hand. Place some grease in one hand, and hold bearing in the other hand. (Figure 2) Don't hurry. Force the grease into all the spaces in the bearing.

FIGURE 2



16. After the bearings have been packed, keep them in a clean, covered area until they are needed.

    Obtain instructor's initials here ______________.

BEARINGS
UNIT V-A

PRACTICAL TEST
JOB SHEET #1 — REMOVE AND INSTALL CAMSHAFT BEARING (FRICTION)

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Placed engine on stand or blocks.	______	______
3.	Checked service manual procedure.	______	______
4.	Selected correct puller adapter.	______	______
5.	Removed bearing in correct order.	______	______
6.	Placed bearings on work bench in order.	______	______
7.	Cleaned bearing bores.	______	______
8.	Cleaned oil passages in engine block.	______	______
9.	Installed new cam bearings.	______	______
10.	Checked oil holes after installation.	______	______
11.	Checked in/put away tools and materials.	______	______
12.	Cleaned the work area.	______	______
13.	Used proper tools correctly.	______	______
14.	Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15.	Practiced safety rules throughout procedure.	______	______
16.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Camshaft bearings are installed correctly.	4	3	2	1
Oil hole passages are aligned.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BEARINGS
UNIT V-A

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND INSTALL ANTI-FRICTION BEARING

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Removed bearing using slide hammer puller.	______	______
4. Removed bearing using screw type puller.	______	______
5. Removed bearing using hydraulic puller.	______	______
6. Removed bearing using internal type puller.	______	______
7. Removed bearing using push type puller.	______	______
8. Removed bearing using external type puller.	______	______
9. Removed bearing from shaft with a press.	______	______
10. Removed bearing from a bore.	______	______
11. Removed bearing from a shaft with a hammer and driver.	______	______
12. Installed bearing onto shaft with a press.	______	______
13. Installed bearing in a bore with a press.	______	______
14. Installed bearing onto shaft with a hammer and driver.	______	______
15. Checked in/put away tools and materials.	______	______
16. Cleaned the work area.	______	______
17. Used proper tools correctly.	______	______
18. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
19. Practiced safety rules throughout procedure.	______	______
20. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Bearing and shaft are in good condition after removal.	4	3	2	1
Bearing and bore are in good condition after removal.	4	3	2	1
Bearing is installed properly onto shaft.	4	3	2	1
Bearing is installed properly into bore.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BEARINGS
UNIT V-A

PRACTICAL TEST
JOB SHEET #3 — CHECK DETROIT DIESEL IDLER GEAR BEARING PRE-LOAD, SPRING SCALE METHOD

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Used safety precautions.	_____	_____
3. Placed gear assembly into vise.	_____	_____
4. Attached spring scale to bearing assembly.	_____	_____
5. Recorded manual specification.	_____	_____
6. Noted required pull to start gear rotating.	_____	_____
7. Recorded average reading.	_____	_____
8. Removed spring scale and holding fixture.	_____	_____
9. Checked in/put away tools and materials.	_____	_____
10. Cleaned the work area.	_____	_____
11. Used proper tools correctly.	_____	_____
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)	_____	_____
13. Practiced safety rules throughout procedure.	_____	_____
14. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Pre-load of idler gear is within specifications.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BEARINGS
UNIT V-A

PRACTICAL TEST
JOB SHEET #4 — CLEAN AND LUBRICATE (PACK) AN ANTI-FRICTION BEARING

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Used recommended cleaning solvent.	______	______
4. Cleaned bearing in cleaning solvent.	______	______
5. Cleaned bearing with compressed air.	______	______
6. Inspected bearing condition.	______	______
7. Stored bearing properly after cleaning.	______	______
8. Packed bearing properly in packer.	______	______
9. Packed bearing properly by hand.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (____hrs. ____min. ____sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Bearing is cleaned properly.	4	3	2	1
Bearing is packed correctly.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

BEARINGS
UNIT V-A

NAME ______________________ SCORE ____________________

TEST

1. Match the terms related to bearings with the correct definitions.

_____a. Resistance to motion between two bodies in contact

_____b. Force directed sideways or perpendicular to the shaft

_____c. Force directed endways or horizontal to the shaft

_____d. Two hardened steel rings

_____e. Plastic thread which "crushes" to the exact clearance when measuring bearing clearance

_____f. A soft metal used to line bearings (an alloy of lead, tin, antimony, and other metals)

_____g. Supporting surface for a wheel or shaft that provides a sliding contact between the mating surfaces

_____h. Supporting surface for a wheel or shaft that provides a rolling contact between mating surfaces

_____i. The distance that each half of the bearing extends beyond the bearing seat bore, usually one or two thousandths of an inch

_____j. Adjustment of anti-friction bearing after being secured in the mounting

1. Anti-friction bearing
2. Axial load
3. Babbit
4. Bearing crush
5. Friction
6. Plain bearing
7. Plastigage®
8. Preloading
9. Races
10. Radial load

2. Select true statements concerning the function of bearings by placing an "X" beside the statement(s) that are true.

_____a. Do not reduce friction

_____b. Support moving parts

TEST

_____c. Provide a replaceable wear surface

_____d. Do not reduce wear

_____e. Reduce friction

_____f. Will not support moving parts

_____g. Reduce wear

3. Name two basic types of bearings.

   a. ____

   b. ____

4. Distinguish between axial and radial load forces on bearings by placing an "X" beside the description of axial load forces.

   _____a. Those forces directed endways or horizontal to the shaft

   _____b. Those forces directed sideways or perpendicular to the shaft

5. Match the types of bearings on the right with their advantages and disadvantages.

   _____a. Advantages
      1. Require little space
      2. Low in cost
      3. Quiet operation
      4. Rigid construction

   _____b. Advantages
      1. Low friction operation
      2. Can be packed to reduce frequency of lubrication
      3. More versatile, many designs

   _____c. Disadvantages
      1. High friction operation
      2. Require more frequent lubrication because they cannot be packed

   _____d. Disadvantages
      1. Require more space
      2. Noisier operation
      3. Higher cost
      4. Less rigidity

   1. Plain bearings (bushings)

   2. Anti-friction bearings

TEST

6. Match the illustrations of plain bearings with the correct names.

______a. Solid bearing or sleeve

______b. Split bearing, rolled type

______c. Thrust bearing

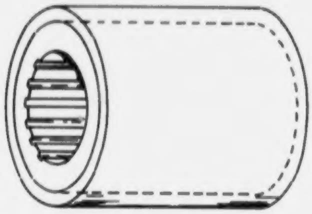
______d. Split bearing with steel back lined with bronze or babbit

______e. Split type constructed of wood, plastic, or rubber

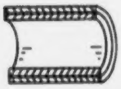
______f. Split bearing used for engine crankshaft

______g. Solid bearing with fluted rubber structure

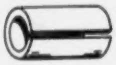
1.



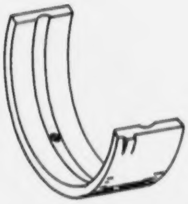
2.



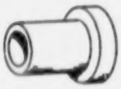
5.



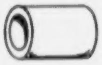
3.



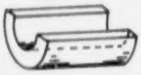
4.



6.



7.



7. List five materials from which bearings may be constructed.

a. ____

b. ____

c. ____

d. ____

e. ____

TEST

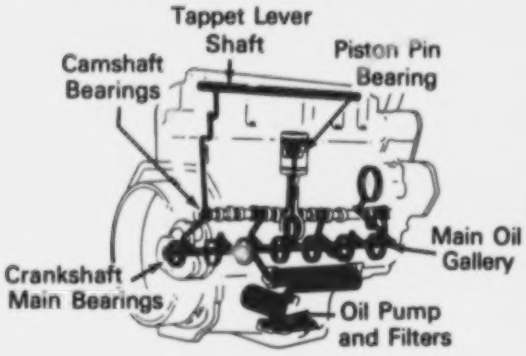
8. List three factors influencing the distribution of lubricant to the bearings.

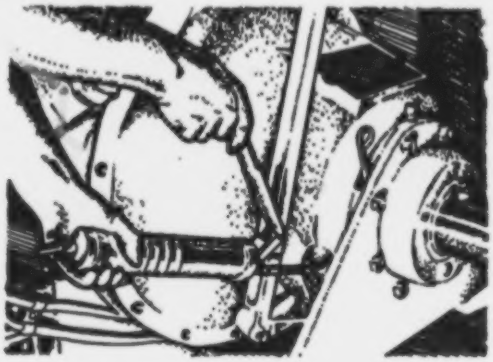
   a.

   b.

   c.

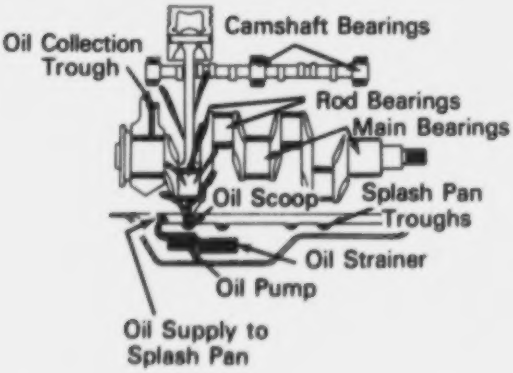
9. Identify the common methods of lubricating bearings.


Tappet Lever Shaft
Camshaft Bearings
Piston Pin Bearing
Main Oil Gallery
Crankshaft Main Bearings
Oil Pump and Filters



   a.

   b.


Camshaft Bearings
Oil Collection Trough
Rod Bearings
Main Bearings
Oil Scoop
Splash Pan
Troughs
Oil Strainer
Oil Pump
Oil Supply to Splash Pan

   c.

10. List five causes of bearing failure in plain bearings.

   a.

   b.

   c.

   d.

   e.

TEST

11. Select true statements concerning the reasons for bearing crush by placing an "X" beside the statement(s) that are true.

______a. Allows bearing to stay hotter

______b. Insures that the bearing remains round

______c. Lets the bearing move in its bore

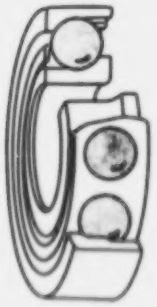
______d. Greater heat dissipation

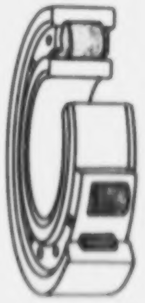
______e. Insert is forced to seat solidly

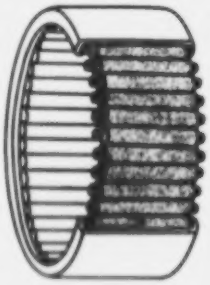
______f. The bearing does not remain round

______g. Avoids any possible movement of the bearing in the seat

12. Identify three types of anti-friction bearings.







a. ____________________ b. ____________________ c. ____________________

13. List three conditions that determine the load carrying capacity of anti-friction bearings.

a. ____

b. ____

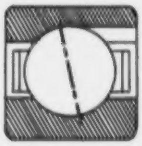
c. ____

TEST

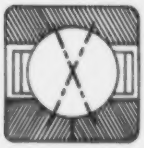
14. Match the names of ball bearing races with the correct type of ball bearings.

1. Angular contact
2. Conrad
3. Full type
4. Split race

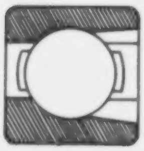
_____a.



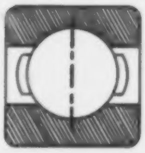
_____b.



_____c.



_____d.

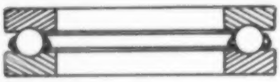


TEST

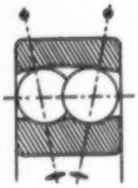
15. Match the names of ball bearings with the correct design.

1. Radial and thrust load
2. Radial load
3. Self-aligning radial load
4. Thrust load

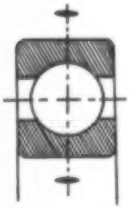
_____a.



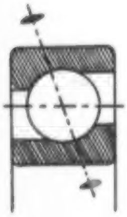
_____b.



_____c.



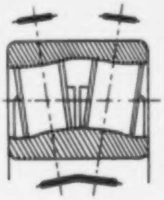
_____d.



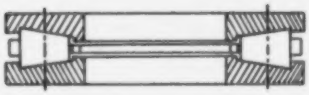
TEST

16. Match the names with the correct type of roller bearings.

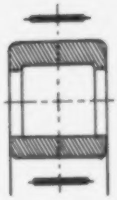
______a.



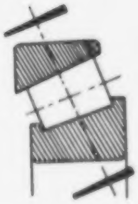
______b



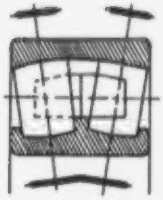
______c.



______d.



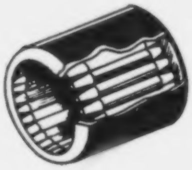
______e.

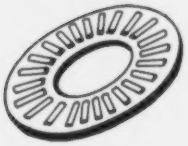


1. Radial load, straight roller
2. Radial and thrust load, tapered roller
3. Self-aligning, radial and thrust load, spherical roller
4. Self-aligning, radial and thrust load, concave roller
5. Thrust load

TEST

17. Identify types of needle bearings.





a. ______________________________ b. ______________________________

18. Select true statements concerning mountings for anti-friction bearings by placing an "X" beside the statement(s) that are true.

______a. Shape must not be distorted.

______b. Rolling elements must not be bound.

______c. Inner and outer races must be aligned.

______d. Axis of each bearing must be aligned with the other.

______e. Usually mounted with both races pressed fit.

______f. Seals are used to retain bearings.

19. Select bearing maintenance tips by placing an "X" beside the tip(s).

______a. Work with clean, approved tools, in clean surroundings.

______b. Use clean solvents and flushing oils.

______c. Install new bearings as they come from the package, without washing, if they are received in a sealed container.

______d. Use wooden mallets or work on a soft wood bench.

______e. Lay bearings out on a clean surface.

______f. Handle bearings with dirty or moist hands.

______g. Keep bearings wrapped in oil-proof paper when not in use.

______h. Wipe bearings, if necessary, only with clean, lint-free rags.

______i. Expose bearings to moisture and dirt.

______j. Use the same container for both cleaning and final rinse of used bearings.

______k. Keep lubricants clean when applying them, and cover the containers when not in use.

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

    a. Remove and install camshaft bearings (friction). (Job Sheet #1)

    b. Remove and install an anti-friction bearing. (Job Sheet #2)

    c. Check Detroit Diesel idler gear bearing pre-load, spring scale method. (Job Sheet #3)

    d. Clean and lubricate (pack) an anti-friction bearing. (Job Sheet #4)

BEARINGS
UNIT V-A

ANSWERS TO TEST

1. a. 5
   b. 10
   c. 2
   d. 9
   e. 7
   f. 3
   g. 6
   h. 1
   i. 4
   j. 8

2. b, c, e, g

3. a. Friction bearing (plain)
   b. Anti-friction bearing

4. a

5. a. 1
   b. 2
   c. 1
   d. 2

6. a. 6
   b. 5
   c. 4
   e. 7
   f. 3
   g. 1

7. Any five of the following:
   a. Cast iron
   b. Soft steel
   c. Hard steel
   d. Copper, brass, and bronze
   e. Copper, lead
   f. Babbit
   g. Aluminum
   h. Plastic
   i. Rubber

8. a. Oil grooves
   b. Bearing clearance
   c. Bearing surface compatibility

9. a. Pressure feed system
   b. Grease gun
   c. Circulating splash

ANSWERS TO TEST

10. Any five of the following:
    a. Dirt
    b. Lack of lubrication
    c. Improper assembly
    d. Misalignment
    e. Overloading
    f. Corrosion

11. b, d, e, g

12. a. Ball
    b. Roller
    c. Needle

13. a. Size of bearing
    b. Number of rolling elements
    c. Type of race

14. a. 1
    b. 4
    c. 3
    d. 2

15. a. 4
    b. 3
    c. 2
    d. 1

16. a. 4
    b. 5
    c. 1
    d. 2
    e. 3

ANSWERS TO TEST

17. a. Radial load
    b. Thrust load

18. a, b, c, d

19. a, b, c, e, g, h, k

20. Performance skills evaluated to the satisfaction of the instructor

SEALS
UNIT VI-A

UNIT OBJECTIVE

After completion of this unit, the student should be able to list uses of seals and name places where dynamic and static seals are used. The student should also be able to match the names of the dynamic seals to the functions and install a radial lip type seal. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to seals with the correct definitions.
2. List uses of seals.
3. Identify types of seals and their uses.
4. Name places where dynamic seals are used.
5. Name places where static seals are used.
6. Match names of dynamic seals with the functions.
7. Match static seals with functional location.
8. Match terms related to sealants with the correct definitions.

OBJECTIVE SHEET

9. Demonstrate the ability to:

    a. Install a radial lip type seal. (Job Sheet #1)

    b. Remove rear main seal and wear sleeve. (Job Sheet #2)

    c. Install rear main seal and wear sleeve. (Job Sheet #3)

SEALS
UNIT VI-A

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Display several types of dynamic and static seals including O-rings, gaskets and diaphragms.
2. Have students make a list concerning where different seals are used.
3. Have students identify where the lip faces on different types of seals.
4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Shop Manual.* Columbus, IN: Cummins Engine Company, Inc., 1981.

B. *Fundamentals of Service: Bearings and Seals.* 3rd ed. Moline, IL: Deere and Company, 1980.

C. *Gasket Installation Manual.* Skokie, IL: Fel-Pro Inc., 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

Filmstrips

A. *Cat Maintenance Aids — Anaerobic Adhesive Sealants* (58 slides and script)
Caterpillar Tractor Co.
Literature Orders Section
1335 S.W. Washington
Peoria, IL 61602

B. *Bearings and Seals* (125 slides)
Deere and Company
Distribution Service Center
1400 Third Avenue
Moline, IL 61265

SEALS
UNIT VI-A

INFORMATION SHEET

I. **Terms and definitions**

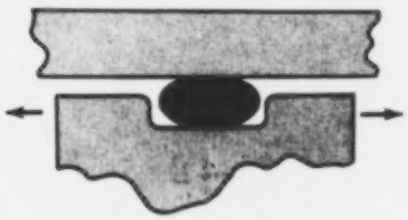
- A. Cure — A chemical process which occurs in sealant allowing it to set up firm
- B. Dynamic — Moving; relating to force
- C. Gasket — Type of static seal
- D. Metallic gasket — A gasket made of metal or combinational metal materials; used for higher pressures and temperatures
- E. Nonmetallic gasket — A gasket made of soft material containing no metal; used for lower pressures
- F. Sealant — Similar to gaskets except applied as a liquid or paste
- G. Static — Without motion; still or fixed
- H. Static seal — Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other

II. **Uses of seals**

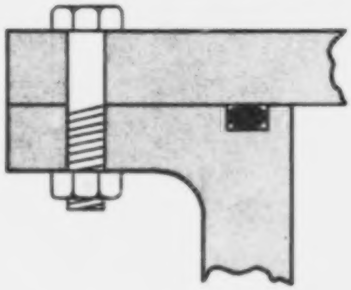
- A. To keep in fluids
- B. To keep out dirt
- C. To hold pressures or vacuums

III. **Basic types of seals and their uses**

A. Dynamic — To seal moving parts



B. Static — To seal fixed parts



INFORMATION SHEET

IV. **Places where dynamic seals are used**

A. Shafts and rods

B. Compression packings

C. Piston rings

V. **Places where static seals are used**

A. Gaskets

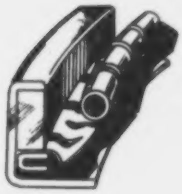
B. O-rings

C. Packings

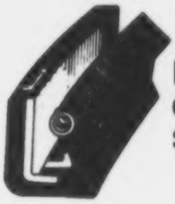
VI. **Dynamic seals and their functions**

A. Radial lip — Used on systems which have moving shafts

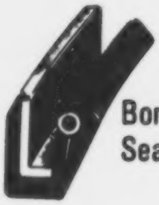
(NOTE: Lip seals may be bonded or assembled and are classified by lip types: single lip, double lip, and dual lip.)



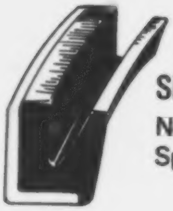
Assembled Seal



Double Lip Seal
One Lip
Spring-Loaded

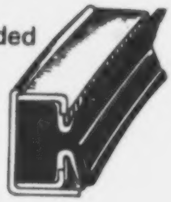


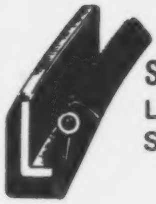
Bonded Seal



Single Lip Seal
Not
Spring-Loaded

Dual Lip Seal
Both Lips
Spring-Loaded



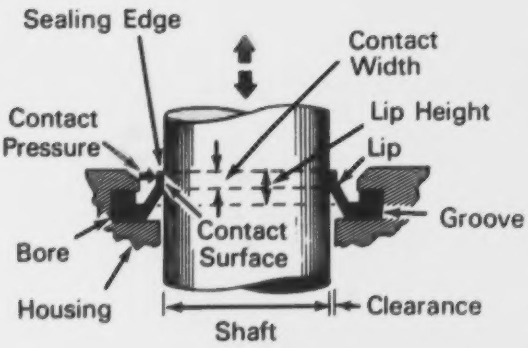


Single Lip Seal
Lip
Spring-Loaded

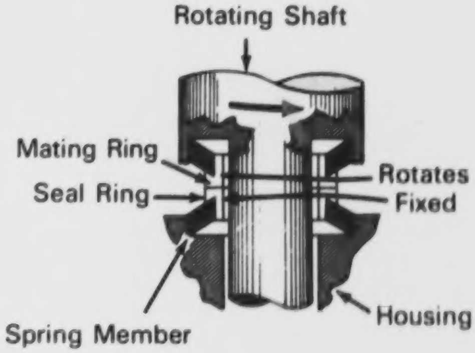
INFORMATION SHEET

B. Exclusion — Used to prevent entry of foreign material into the moving parts of machinery

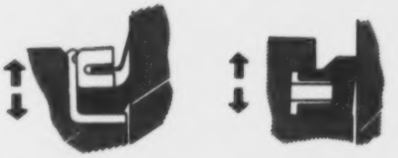
(NOTE: Exclusion seals are classified into four general groups: wipers, scrapers, axial seals, and boots.)


Sealing Edge
Contact Width
Contact Pressure
Lip Height
Lip
Groove
Contact Surface
Bore
Housing
Shaft
Clearance

Radial Exclusion Seal


Rotating Shaft
Mating Ring
Seal Ring
Rotates
Fixed
Spring Member
Housing

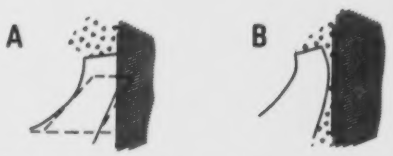
Axial Seal



Conical Scraper

Ring Scraper

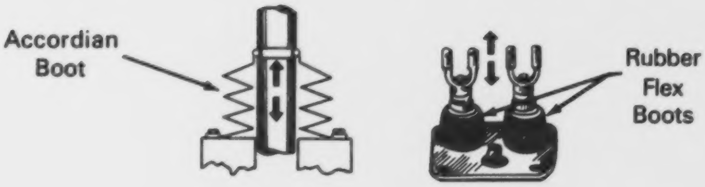
Scrapers



Proper Operation

Lack Of Contact Pressure

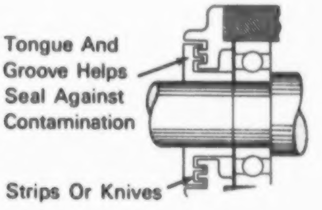
Lips Of Wiper Seals


Accordian Boot
Rubber Flex Boots

Boots Which Protect Reciprocating Shafts

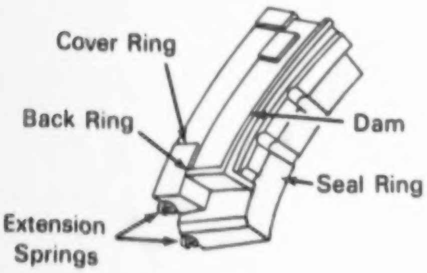
C. Clearance — Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

(NOTE: Clearance seals are classified as labyrinth seals or bushings [rings], and some leakage is permitted.)

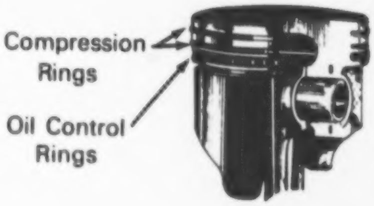

Tongue And Groove Helps Seal Against Contamination
Strips Or Knives

D. Ring — Depend on surface contact between the seal and the moving part and the seal and the stationary part

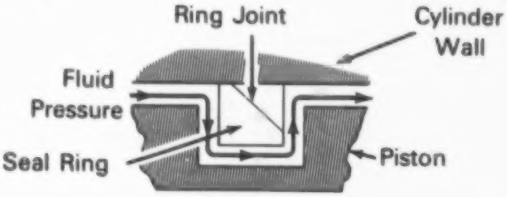
(NOTE: Ring seals are split-ring type for reciprocating parts and circumferential for rotary parts.)


Cover Ring
Back Ring
Dam
Seal Ring
Extension Springs

Circumferential Seal


Compression Rings
Oil Control Rings

Split-Ring Seals On An Engine Piston

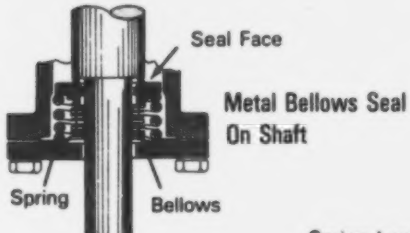

Ring Joint
Cylinder Wall
Fluid Pressure
Seal Ring
Piston

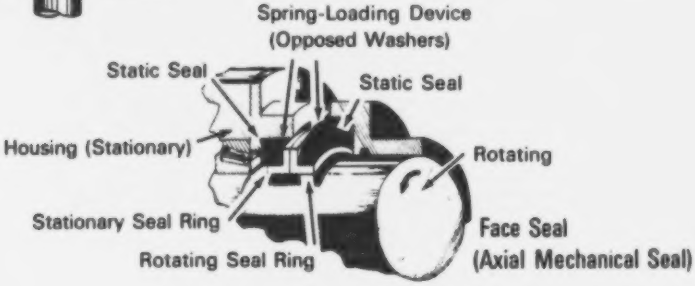
How A Split Ring Seals

INFORMATION SHEET

E. Face — Form a running seal between flat, precision-finished surfaces

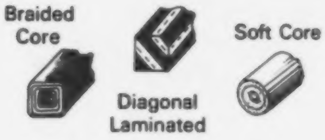
(NOTE: All face seals have a rotating seal ring, stationary seal ring, spring loaded devices, and static seals.)


Seal Face
Metal Bellows Seal On Shaft
Spring
Bellows

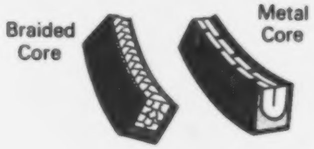

Spring-Loading Device (Opposed Washers)
Static Seal
Static Seal
Housing (Stationary)
Rotating
Stationary Seal Ring
Rotating Seal Ring
Face Seal (Axial Mechanical Seal)

F. Compression packings — Create a seal when squeezed between the throat of a stuffing box and its gland

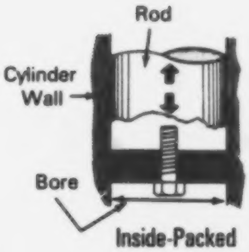
(NOTE: Three classes of packings are fabric, metallic, and plastic.)


Braided Core
Diagonal Laminated
Soft Core

Fabric Packings

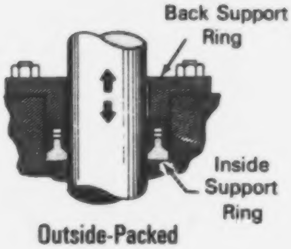

Braided Core
Metal Core

Metallic Packings


Rod
Cylinder Wall
Bore

Inside-Packed

Inside And Outside-Packed Installations

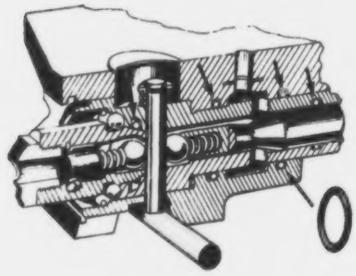

Back Support Ring
Inside Support Ring

Outside-Packed

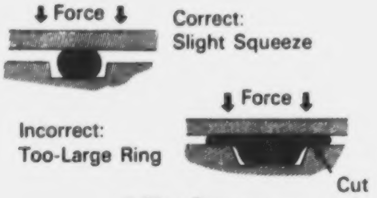
INFORMATION SHEET

G. Molded packings — Fluid being sealed supplies the pressure to seal the packings against the wearing surface (Transparency 1)

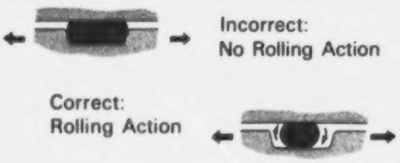
(NOTE: The major types of packing are lip and squeeze. Lip types include flange, cup, U-cup, U-ring, and V-ring packings. Squeeze types include O-rings and related forms, plus felt.)



Squeeze-Type Packings
(O-Rings Shown)


Force
Correct:
Slight Squeeze
Force
Incorrect:
Too-Large Ring
Cut

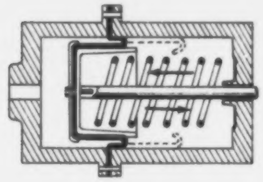
O-Ring Squeeze


Incorrect:
No Rolling Action
Correct:
Rolling Action

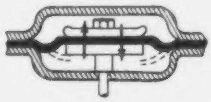
O-Ring Rolling Action

H. Diaphragm seal — Dividing membrane which spans the gap between a moving and stationary member

(NOTE: Diaphragm seals may be either rolling or flat. The rolling types are like long travel bellows.)



Rolling Diaphragm

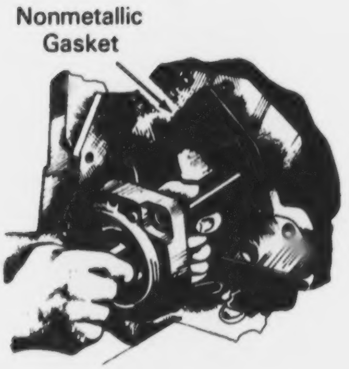


Flat Diaphragm

INFORMATION SHEET

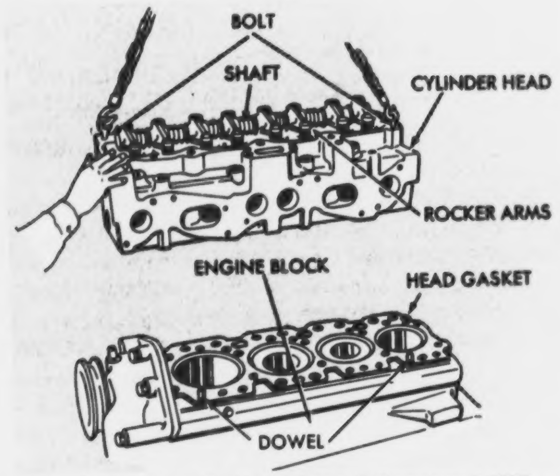
VII. Types of static seals

A. Nonmetallic


Nonmetallic
Gasket

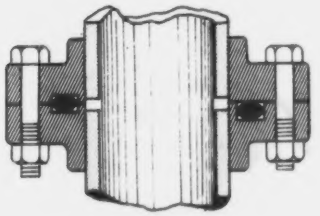
Low-Pressure Application

B. Metallic


BOLT
SHAFT
CYLINDER HEAD
ROCKER ARMS
ENGINE BLOCK
HEAD GASKET
DOWEL

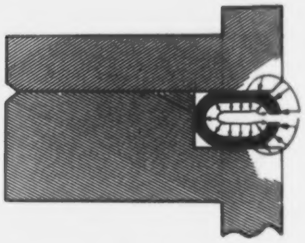
(Reproduced by permission of Deere & Company, © 1987 Deere & Company. All rights reserved.)

C. Static O-rings (nonmetallic)



In Flange Joints
(Two Types Of Rectangular
Grooves Shown)

D. Static O-rings (metallic)



In Static Use

VIII. Categories of sealants (Transparency 2)

A. Hardening — Some will set up firm while others will remain flexible after curing.

B. Non-hardening — Stay wet after application and never truly dry.

INFORMATION SHEET

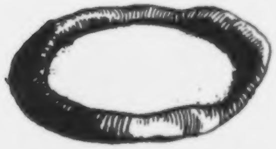
C. Tapes — Available in a variety of backings and adhesives usually in pressure sensitive or solvent activated adhesive backs.

(CAUTION: When using tape, check on torquing specification.)

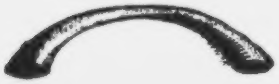
D. RTV — A sealant which forms a rubber seal by absorbing moisture from the air

(NOTE: The initials RTV stand for "Room Temperature Vulcanizing.")

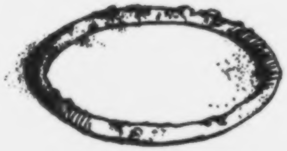
Dynamic Seals



Swollen O-Ring:
Use of Wrong Fluid

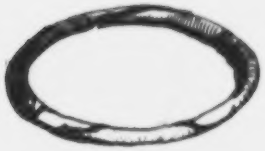


Flattened O-Ring:
Use of Low-Grade Rings

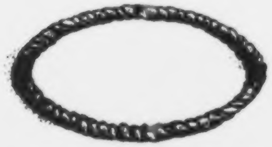


Dirty O-Ring:
Poor Storage or
Contaminated System

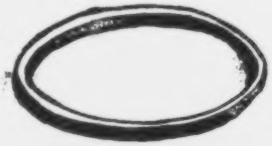
O-Ring Failures



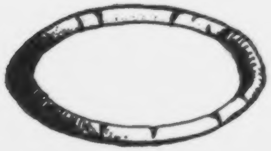
Cut O-Ring:
Shaft Damage
or Installed Wrong



Twisted O-Ring:
Installed Wrong

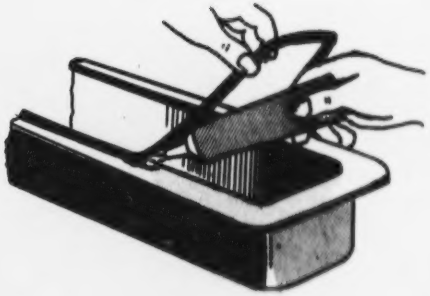


Worn O-Ring:
Lack of Lubrication

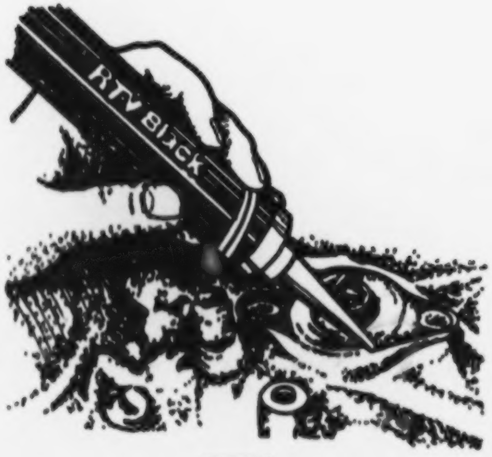


Cracked O-Ring:
Too Much Heat

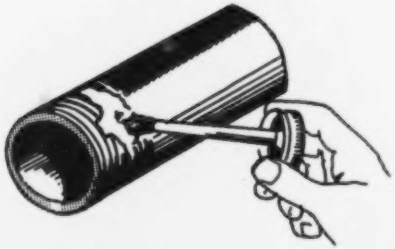
Static Seals



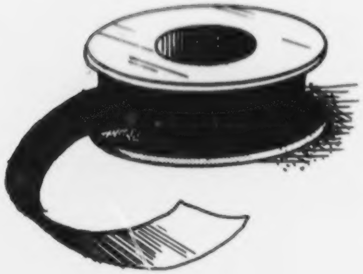
Tube



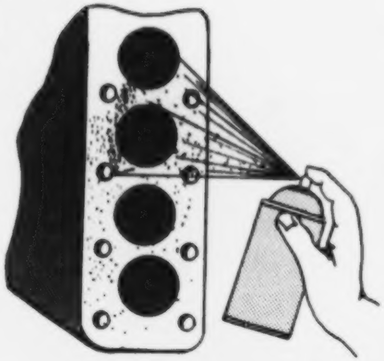
RTV



Brush



Teflon Tape



Spray

SEALS
UNIT VI-A

JOB SHEET #1 — INSTALL A RADIAL LIP TYPE SEAL

A. Tools and materials

1. Safety glasses
2. Appropriate service manual
3. Shop towels (lint free)
4. Basic hand tool assortment
5. Seal installation tools recommended in appropriate service manual
6. Emery cloth
7. Gasket cement

B. Procedure

(CAUTION: Follow all shop safety procedures.)

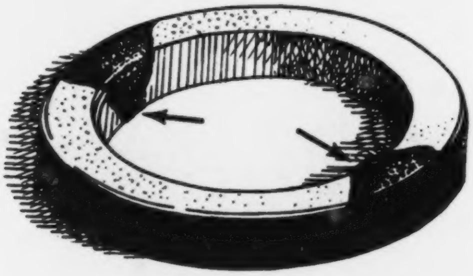
1. Clean the shaft or bore area and inspect for damage.
2. File or stone any burrs or bad nicks, and polish with fine emery cloth to a ground finish.
3. Clean area and remove all metal particles.
4. Lubricate the seal, especially any lips, and the shaft to ease installation, using the system fluid to lubricate the seal and shaft.

   (NOTE: On seals with single lips, the lip should normally face in toward the system lubricant. This is usually the garter spring side.)

5. With metal cased seals, coat the seal's outside diameter with a thin film of gasket cement to prevent bore leakage. Do not allow excess cement to run onto sealing lips. (Figure 1)

   (NOTE: Precoated seals do not require cement on the bore fit.)

   FIGURE 1



JOB SHEET #1

6. Install the seal. (Figures 2 and 3)

(NOTE: The use of a factory specified installation tool may be required. This is very important with pressed-in seals. If a seal driving tool is not available, use a circular ring such as an old bearing race that contacts the seal case near the outer diameter, or use a square wooden block. Do not use sharp tools, and never press on the sealing lip; press only the outer metal case.)

FIGURE 2

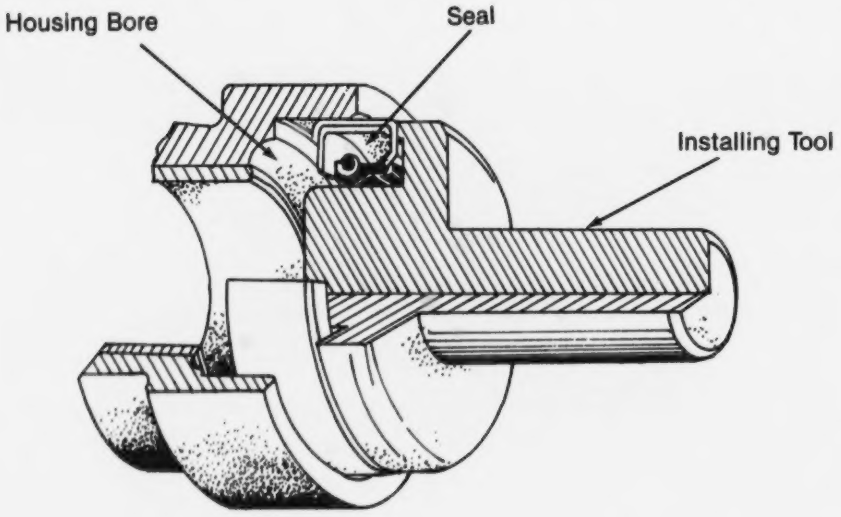
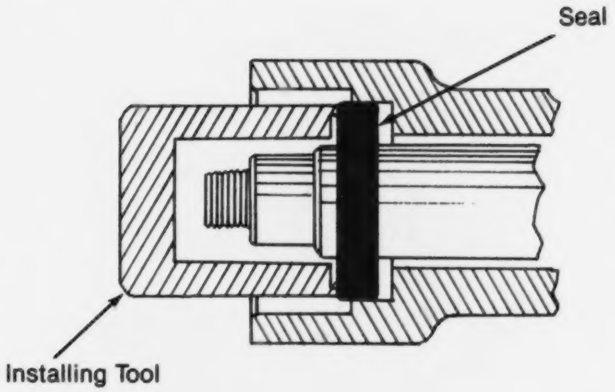

Housing Bore
Seal
Installing Tool

FIGURE 3


Seal
Installing Tool

JOB SHEET #1

7. Protect the sealing lip when installing the seal over sharp corners of shafts, keyways, or splines. (Figures 4 and 5)

   (NOTE: Shim stock can also be used to protect seals when installing them over sharp edges such as shaft splines. Place rolled plastic shim stock over the sharp edge, then pull it out after the seal is in place.)

FIGURE 4

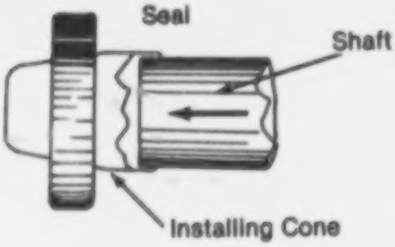
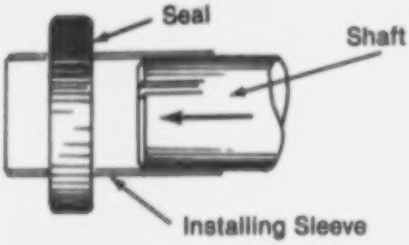

Seal
Shaft
Installing Cone

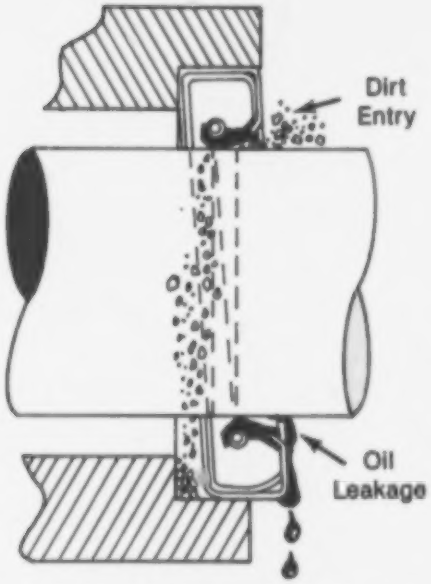
FIGURE 5


Seal
Shaft
Installing Sleeve

8. Drive the seal in evenly to prevent "cocking" of the seal. (Figures 6 and 7)

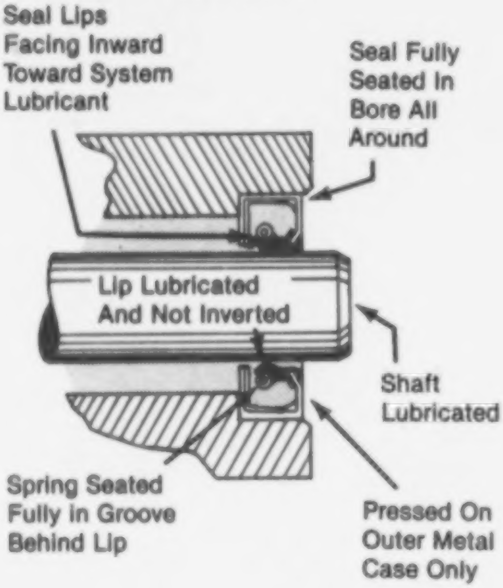
   (NOTE: A cocked seal allows oil to leak out and dirt to enter as shown. Be careful not to bend or "dish" the flat metal area of metal cased seals. This causes the lips to be distorted.)

FIGURE 6


Dirt
Entry
Oil
Leakage

Cocked Seals Allow Dirt To Enter And Oil To Leak Out

FIGURE 7


Seal Lips
Facing Inward
Toward System
Lubricant
Seal Fully
Seated In
Bore All
Around
Lip Lubricated
And Not Inverted
Shaft
Lubricated
Spring Seated
Fully in Groove
Behind Lip
Pressed On
Outer Metal
Case Only

(NOTE: Some seals require checking for seal runout.)

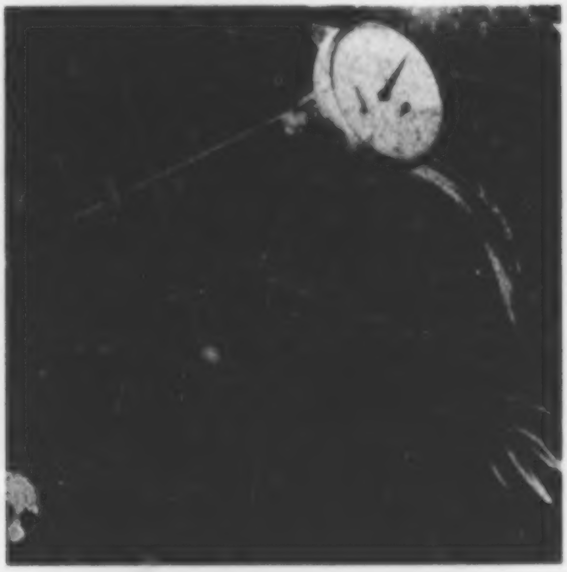
JOB SHEET #1

9. Always check the unit by hand after assembly for free operation (before starting up the system, if possible).

   (NOTE: Try to prevent dirt and grit from falling on shafts and being carried into the seal. This material can quickly damage the seal or score the metal surfaces.)

   (CAUTION: After seal is installed, check seal runout with a dial indicator. See Figure 8.)

FIGURE 8



10. Run in new lip type seal; check for leaks.

    (NOTE: When a new lip type seal is installed on a clean shaft, a break in period of a few hours is required to seat the seal lip with the shaft surface. During this period, the seal polishes a pattern on the shaft, and the shaft in turn seats the lip contact, wearing away the knife-sharp lip contact to a narrow band. During this period, slight seepage may occur. After seating, the seal should perform without any measurable leakage.)

    Obtain instructor's initials here ______________.

SEALS
UNIT VI-A

JOB SHEET #2 — REMOVE REAR MAIN SEAL AND WEAR SLEEVE

A. Tools and materials

1. Safety glasses
2. Appropriate service manual
3. Clean shop towels (lint free)
4. Basic hand tools
5. Seal removing tool

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove rear main oil seal housing from engine. (Figure 1)

FIGURE 1

Oil Seal Housing

2. Remove and discard seal housing gasket.
3. Support housing on wooden blocks, and press seal from housing with seal remover tool.

   (NOTE: If a seal remover tool is not available, use a hammer and punch. Be careful not to damage housing.)

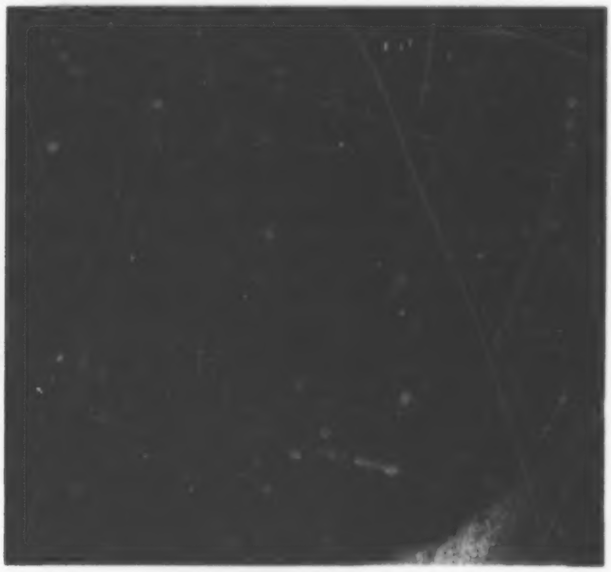
JOB SHEET #2

4. Check for nicks or burrs in the housing bore. If they are present, remove with a file or emery cloth.

5. Remove wear sleeve from the crankshaft; score (cut) lightly with a dull chisel. (Figure 2)

   (CAUTION: DO NOT score (cut) too deeply or the crankshaft rear flange might be damaged.)

   FIGURE 2



6. Inspect the crankshaft flange for burrs or nicks. If necessary, clean flange with a file and fine emery cloth.

   Obtain instructor's initials here ______________.

SEALS
UNIT VI-A

JOB SHEET #3 — INSTALL REAR MAIN SEAL AND WEAR SLEEVE

A. Tools and materials

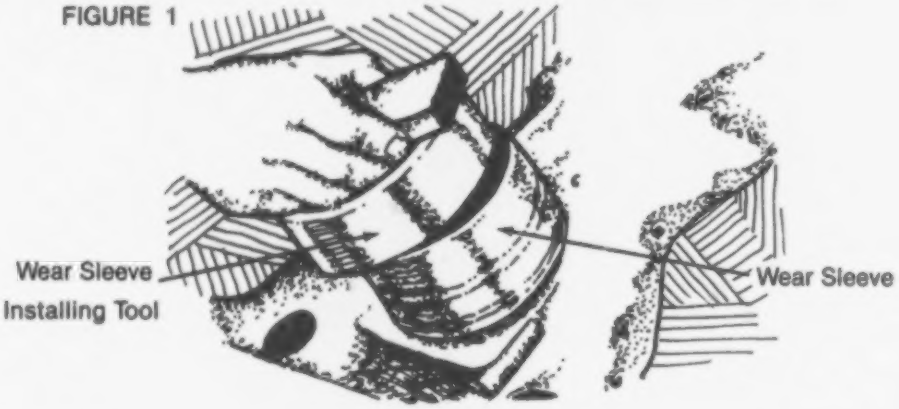
1. Safety glasses
2. Appropriate service manual
3. Clean shop towels (lint free)
4. Basic hand tools
5. Seal installing tool
6. Wear sleeve installing tool

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Start seal wear sleeve onto the crankshaft flange by hand. (Figure 1)

FIGURE 1



2. Avoid heavy pressure or cocking of the wear sleeve.
3. Place the installing tool against the wear sleeve.
4. Drive the wear sleeve onto the crankshaft to service manual specifications.

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #3

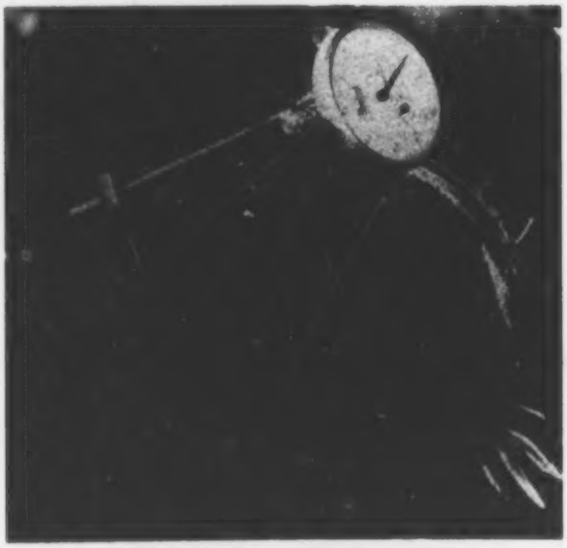
5. Clean the crankshaft flange and wear sleeve with a clean shop towel.

6. Install the seal housing and a new gasket onto the cylinder block.

7. Tighten the capscrews only enough to hold the seal housing into position.

8. Check the alignment of the seal housing with the crankshaft using a dial indicator. (Figure 2)

FIGURE 2



9. Tighten seal housing cap screws to specifications after you have aligned the housing.

   Obtain instructor's initials here ____________ before proceeding to next step.

10. Recheck alignment before removing dial indicator.

11. Push the oil seal onto the crankshaft up to the seal housing.

    (CAUTION: Check manufacturer's specifications on installation because some manufacturers require oil on the lip of seal, while others recommend not putting oil on the lip.)

JOB SHEET #3

12. Drive seal into seal housing using installation tool. (Figure 3)

FIGURE 3

Installation Tool

(CAUTION: Check with specification on how far to drive seal into housing.)

Obtain instructor's initials here _____________.

SEALS
UNIT VI-A

PRACTICAL TEST
JOB SHEET #1 — INSTALL A RADIAL LIP TYPE SEAL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Cleaned the shaft.	______	______
3. Cleaned the housing bore.	______	______
4. Lubricated the seal lip with oil.	______	______
5. Coated the seal's outside diameter with sealant.	______	______
6. Used correct tool to drive seal into bore.	______	______
7. Used correct tool to drive seal onto shaft.	______	______
8. Checked seal runout with bore.	______	______
9. Seated the new seal.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Seal is installed in bore correctly.	4	3	2	1
Seal is installed onto the shaft correctly.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SEALS
UNIT VI-A

PRACTICAL TEST
JOB SHEET #2 — REMOVE REAR MAIN SEAL AND WEAR SLEEVE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used safety precautions.	______	______
3. Removed seal housing.	______	______
4. Pressed seal out of housing.	______	______
5. Removed nicks and burrs from housing.	______	______
6. Scored (cut) wear sleeve.	______	______
7. Removed wear sleeve.	______	______
8. Removed nicks and burrs from crankshaft.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Seal is removed properly from housing.	4	3	2	1
Wear sleeve is removed properly.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SEALS
UNIT VI-A

PRACTICAL TEST
JOB SHEET #3 — INSTALL REAR MAIN SEAL AND WEAR SLEEVE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Used safety precautions.	______	______
3.	Installed seal housing onto crankshaft.	______	______
4.	Installed seal housing onto cylinder block.	______	______
5.	Checked housing alignment.	______	______
6.	Installed oil seal into housing.	______	______
7.	Checked in/put away tools and materials.	______	______
8.	Cleaned the work area.	______	______
9.	Used proper tools correctly.	______	______
10.	Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11.	Practiced safety rules throughout procedure.	______	______
12.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Wear sleeve is installed properly.	4	3	2	1
Rear main seal is installed properly.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SEALS
UNIT VI-A

NAME ______________________________ SCORE ______________________

TEST

1. Match the terms related to seals with the correct definitions.

_____a. Moving; relating to force

_____b. Without motion; still or fixed

_____c. Similar to gaskets except applied as a liquid or paste

_____d. Device which maintains a barrier against the transfer of fluids across two mating surfaces which do not move relative to each other

_____e. Type of static seal

_____f. A gasket made of metal or combinational metal materials; used for higher pressures and temperature

_____g. A gasket made of soft material containing no metal; used for lower pressures

_____h. A chemical process which occurs in sealant allowing it to set up firm

1. Cure
2. Dynamic
3. Gasket
4. Metallic gasket
5. Nonmetallic gasket
6. Sealant
7. Static
8. Static seal

2. List three uses of seals.

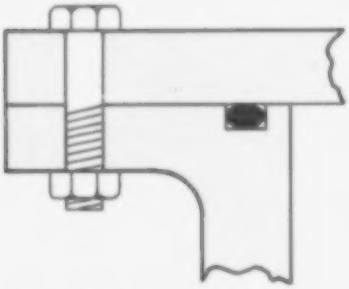
a. ____

b. ____

c. ____

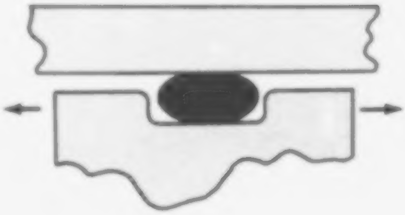
TEST

3. Identify the basic types of seals and their uses.



a. To seal fixed parts

____



b. To seal moving parts

____

4. Name three places where dynamic seals are used.

a. ____

b. ____

c. ____

5. Name three places where static seals are used.

a. ____

b. ____

c. ____

TEST

6. Match the names of dynamic seals with their functions.

_____a. Used on systems which have moving shafts

_____b. Used to prevent entry of foreign material into the moving parts of machinery

_____c. Limit leakage by closely controlling the annular clearance between a rotating or reciprocating shaft and stationary bushing

_____d. Depend on surface contact between the seal and the moving part and the seal and the stationary part

_____e. Form a running seal between flat, precision finished surfaces

_____f. Create a seal when squeezed between the throat of a stuffing box and its gland

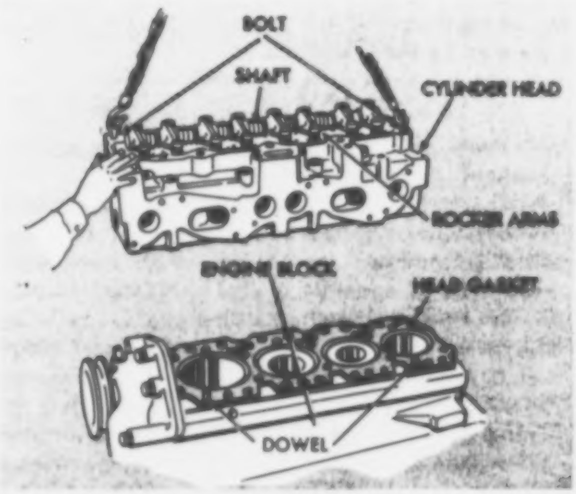
_____g. Fluid being sealed supplies the pressure to seal the packings against the wearing surface

_____h. Dividing membrane which spans the gap between a moving and stationary member

1. Clearance
2. Compression packings
3. Diaphragm seal
4. Exclusion
5. Face
6. Molded packings
7. Radial lip
8. Ring

7. Match static seals with their functional location by placing the correct number beside the proper location.

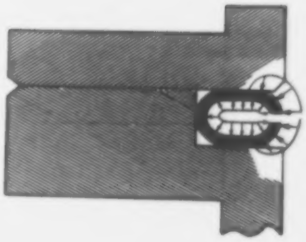
_____a.



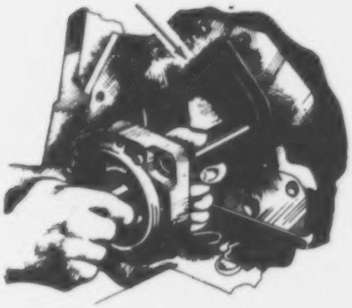
1. Metallic
2. Nonmetallic
3. Static O-ring (metallic)
4. Static O-ring (nonmetallic)

TEST

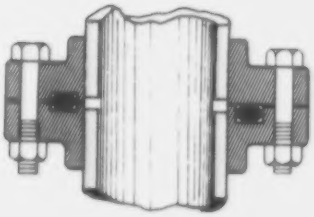
_____b.



_____c.



_____d.



TEST

8. Match terms related to sealants with the correct definitions.

_____a. A sealant which forms a rubber seal by absorbing moisture from the air

_____b. Some will set up firm while others will remain flexible after curing.

_____c. Available in a variety of backings and adhesives usually in pressure sensitive or solvent activated adhesive backs

_____d. Stay wet after application and never truly dry

1. Hardening types
2. Non-hardening types
3. RTV
4. Tapes

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Demonstrate the ability to:

   a. Install a radial lip type seal. (Job Sheet #1)

   b. Remove rear main seal and wear sleeve. (Job Sheet #2)

   c. Install rear main seal and wear sleeve. (Job Sheet #3)

SEALS
UNIT VI-A

ANSWERS TO TEST

1. a. 2 e. 3
   b. 7 f. 4
   c. 6 g. 5
   d. 8 h. 1

2. a. To keep in fluids
   b. To keep out dirt
   c. To hold pressures or vacuums

3. a. Static
   b. Dynamic

4. a. Shafts and rods
   b. Compression packings
   c. Piston rings

5. a. Gaskets
   b. O-rings
   c. Packings

6. a. 7
   b. 4
   c. 1
   d. 8
   e. 5
   f. 2
   g. 6
   h. 3

7. a. 1
   b. 3
   c. 2
   d. 4

8. a. 3
   b. 1
   c. 4
   d. 2

9. Performance skills evaluated to the satisfaction of the instructor

ENGINE OPERATING PRINCIPLES
UNIT I-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify basic parts of a diesel engine and match these parts with the functions. The student should also be able to discuss the operation of the diesel engine, distinguish the differences in the diesel engine and the gasoline engine, and explain the basic difference between a four-stroke cycle and a two-stroke cycle engine. Competencies will be demonstrated by completing the assignment sheets and unit test with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to engine operating principles with the correct definitions.
2. Identify basic parts of a diesel engine.
3. Match basic diesel engine parts with the functions.
4. Arrange in order the sequence of operation of the diesel engine.
5. Complete a list of what happens during each stroke of a four-stroke cycle engine.
6. Differentiate between two-stroke and four-stroke cycle engines.
7. Differentiate between the characteristics of two-stroke cycle and four-stroke cycle engines.
8. Differentiate between diesel engines and gasoline engines.
9. Locate intake and exhaust valves on an engine. (Assignment Sheet #1)
10. Locate TDC #1 cylinder on compression stroke of an engine. (Assignment Sheet #2)

ENGINE OPERATING PRINCIPLES
UNIT I-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Have students collect information on different engine types.
2. Have students make a list of different parts suppliers in their area.
3. Have students measure bore and stroke on an engine.
4. Have students rotate an engine in proper direction of engine rotation and watch rocker arm operation.
5. Have students use a shop manual and find valve location of an engine.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

B. *Detroit Diesel Allison, 92 Series Service Manual.* Detroit, MI: General Motors Corp., 1984.

REFERENCES USED IN DEVELOPING THIS UNIT

C. *Fundamentals of Service: Engines*. 5th ed. Moline, IL: Deere and Company, 1980.

D. Schulz, Erich J. *Diesel Mechanics*. 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill, 1983.

E. *Shop Manual*. Columbus, IN: Cummins Engine Company, 1981.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

The Engine Book — An Introduction to Diesel Engines. 50 pages.
Caterpillar Tractor Company
Literature Orders Section
1335 W. Washington
Peoria, IL 61602

B. Filmstrips

1. *Basic Diesel Engines*. 83 slides
   Caterpillar Tractor Co.
   Literature Order Section
   1335 W. Washington
   Peoria, IL 61602

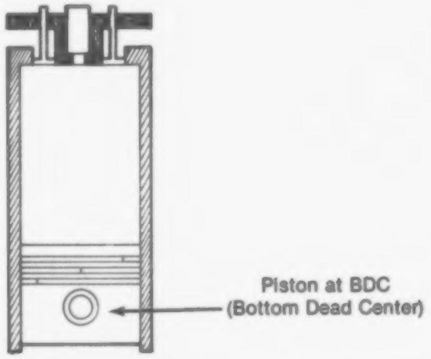
2. *Engines*. 300 slides
   Deere and Company
   Distribution Service Center
   1400 Third Avenue
   Moline, IL 61265

ENGINE OPERATING PRINCIPLES
UNIT I-B

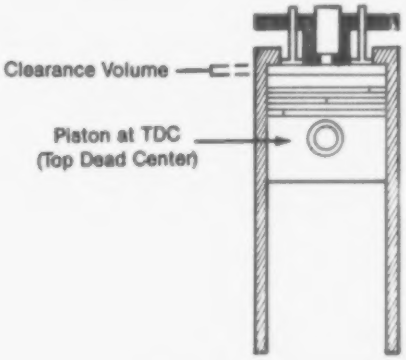
INFORMATION SHEET

I. **Terms and definitions**

A. BDC (Bottom Dead Center) — Piston at lowest point of travel


Piston at BDC
(Bottom Dead Center)

B. Clearance volume — Total space between the cylinder head and the piston when the piston is at its highest position in the cylinder


Clearance Volume
Piston at TDC
(Top Dead Center)

C. Combustion — Action or operation of burning

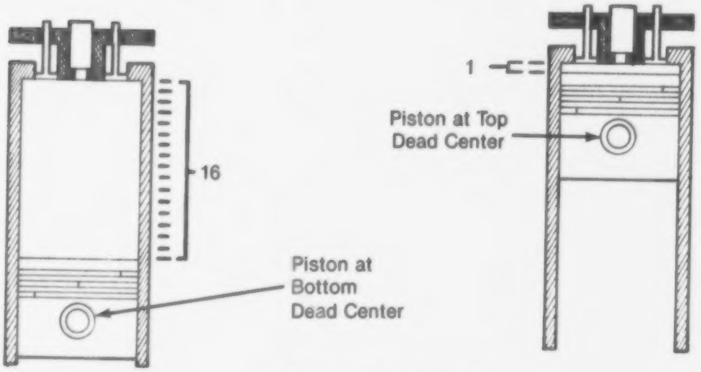
D. Compression — The reduction in volume of gases trapped in the cylinder caused by the upward motion of the piston

E. Compression ignition — Ignition of the fuel by the heat of compression

INFORMATION SHEET

F. Compression ratio — Ratio of whole cylinder volume to least cylinder volume (Transparency 1)

Example: If cylinder volume is 80 cubic inches and clearance volume is 5 cubic inches, then the compression ratio is 80÷5 = 16 or 16:1 ratio


16
Piston at Bottom Dead Center
1
Piston at Top Dead Center

Compression Ratio 16:1

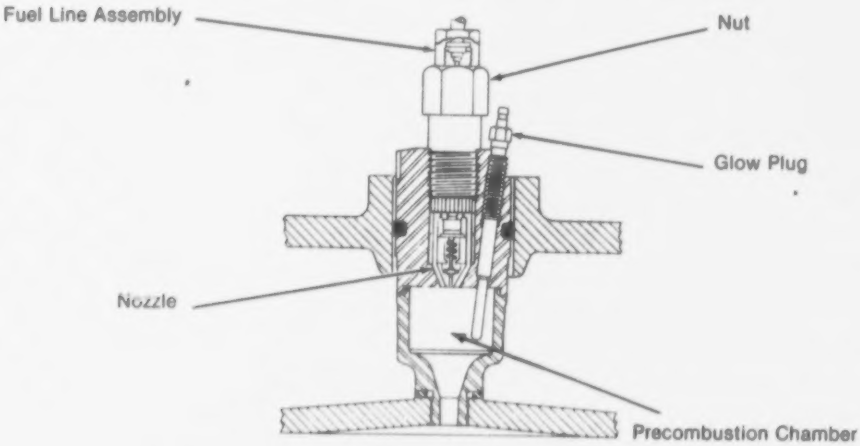
G. Cycle — Series of events that repeat themselves in a regular sequence

H. Engine speed — Crankshaft revolutions per minute

I. Piston crown — Surface shape of the top of the piston

J. Power control — Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

K. Pre-combustion chamber — Cavity in the cylinder head of some diesels where some burning of fuel first takes place

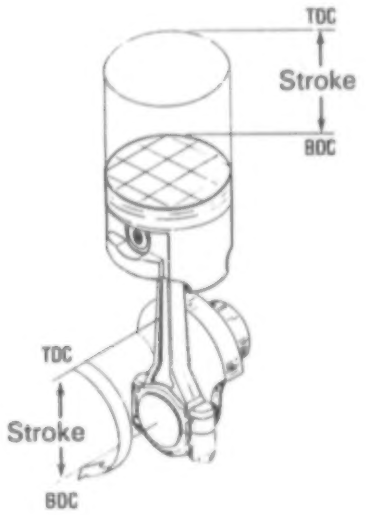

Fuel Line Assembly
Nut
Glow Plug
Nozzle
Precombustion Chamber

(Courtesy of Caterpillar Inc.)

INFORMATION SHEET

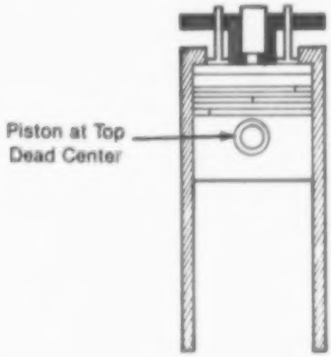
L. Scavenging — The displacement of exhaust gas from the cylinder by fresh air

M. Stroke — Distance the piston moves when traveling from TDC to BDC


TDC
Stroke
BDC
TDC
Stroke
BDC

INFORMATION SHEET

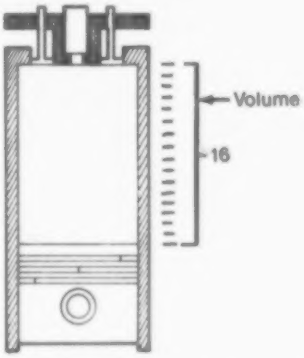
N. TDC (Top Dead Center) — Piston at highest point of travel



O. Temperature — Measure of heat intensity

P. Valve overlap — Period of crankshaft rotation during which both intake and exhaust valves are open

Q. Volume — Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head (Transparency 1)



II. **Basic parts of a diesel engine** (Transparencies 2, 3, and 4)

A. Cylinder block

B. Cylinders

C. Pistons

D. Connecting rod

E. Crankshaft

INFORMATION SHEET

F. Crankshaft gear

G. Camshaft

H. Timing gear

I. Cam lobes

J. Push rods

K. Rocker arm

L. Valves

M. Valve lifter (cam followers)

N. Cylinder head

O. Cooling passageway (including engine oil coolers)

P. Piston pin (wrist pin)

Q. Flywheel

R. Oil pump

S. Oil pan

T. Intake valve

U. Exhaust valve

V. Vibration damper (harmonic balancer)

W. Oil cooler

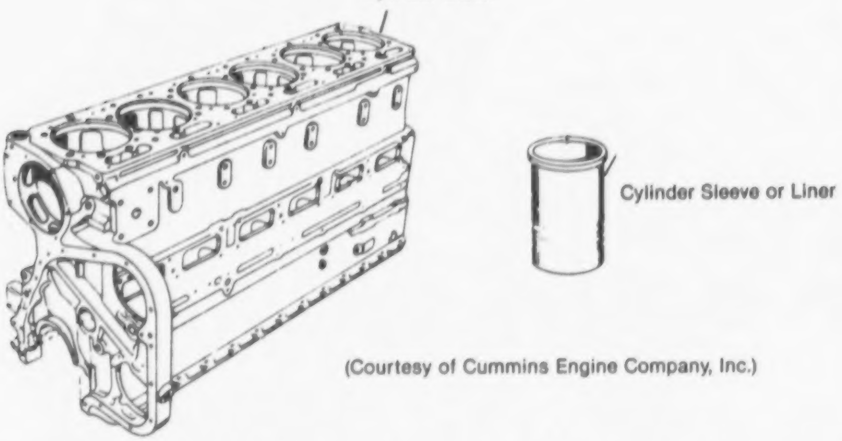
III. **Basic diesel engine parts and their functions** (Transparencies 2, 3, and 4)

A. Cylinder block — Solid casing which includes the cylinders and water jackets

INFORMATION SHEET

B. Cylinders — Holes in the cylinder block containing the pistons

(NOTE: The cylinder can be a sleeve or liner that fits into a cylinder block.)


Cylinder Block
Cylinder Sleeve or Liner

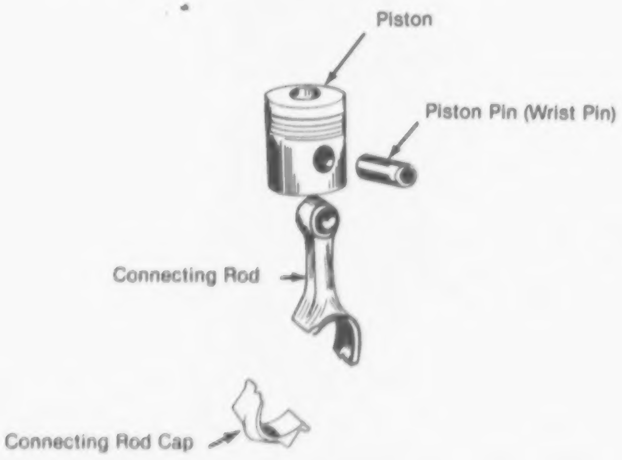
(Courtesy of Cummins Engine Company, Inc.)

C. Pistons — Movable plugs open at one end which transfer force of explosion to the connecting rod

D. Connecting rod — Connecting link between the piston and crankshaft

E. Piston pin — Serves as floating connecting piece for piston and connecting rod

(NOTE: Piston pin is also known as wrist pin.)


Piston
Piston Pin (Wrist Pin)
Connecting Rod
Connecting Rod Cap

A5
100 mm
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
1.0 mm
1.5 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

INFORMATION SHEET

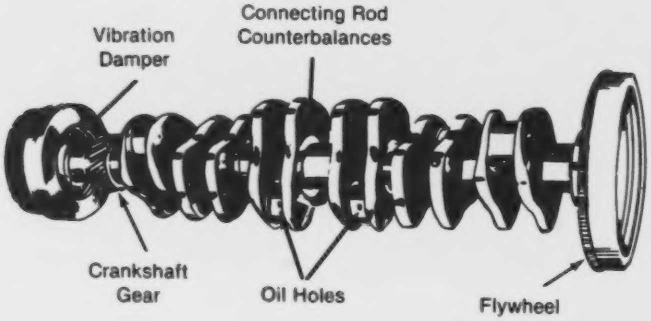
F. Crankshaft — Main shaft of an engine which, turned by connecting rods, changes the reciprocating motion of the piston to rotary motion in the power train

(NOTE: Portions are offset to form throws to which the connecting rods are attached.)

G. Crankshaft gear — Drives the camshaft or idler gear

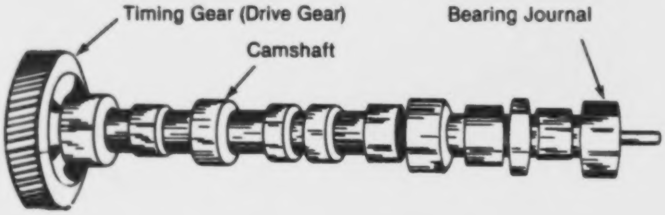
H. Flywheel — Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

I. Vibration damper — A specially designed device mounted to the front of the crankshaft to reduce torsional vibration; also known as harmonic balancer


Vibration Damper
Connecting Rod Counterbalances
Crankshaft Gear
Oil Holes
Flywheel

J. Camshaft — Shaft with cam lobes used to operate the valves

K. Timing gear — A gear attached to the crankshaft that drives the camshaft; regulates speed and performance


Timing Gear (Drive Gear)
Bearing Journal
Camshaft

L. Cam lobes — Eccentrics on the camshaft that operate the valves

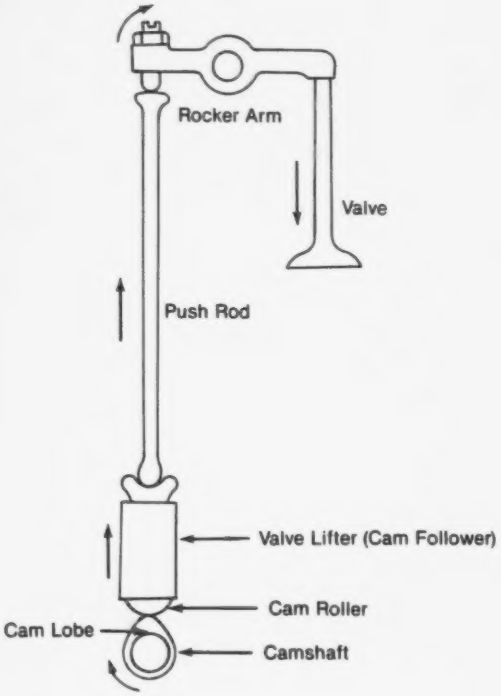
M. Push rods (tubes) — Rod links that transfer motion from the lifter to the rocker arm

INFORMATION SHEET

N. Rocker arm — Transfers motion from push rod to valve to open the valve

O. Valve lifter (cam follower) — Rides on the camshaft so that the cam lobe raises it to operate the valve

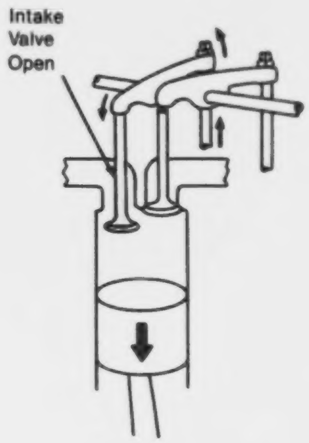
(NOTE: Cam rollers on valve lifter help reduce engine load.)


Rocker Arm
Valve
Push Rod
Valve Lifter (Cam Follower)
Cam Roller
Cam Lobe
Camshaft

INFORMATION SHEET

P. Valves — Open and close the cylinder to allow air to enter or gases to leave the cylinder

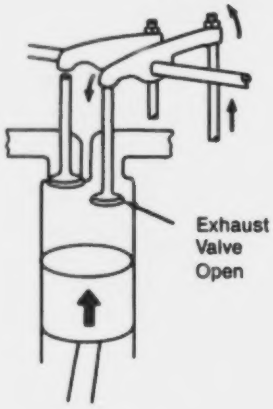
Q. Intake valve — Permits air to enter the cylinder



Intake

(Reproduced by permission of Deere & Company, © 1980 Deere & Company. All rights reserved.)

R. Exhaust valve — Opens and allows exhaust gases to be forced from engine cylinder

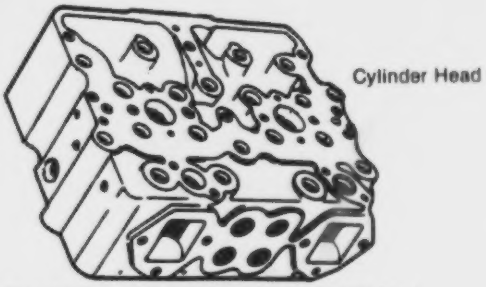


Exhaust

(Reproduced by permission of Deere & Company, © 1980 Deere & Company. All rights reserved.)

INFORMATION SHEET

S. Cylinder head — Metal section bolted to the block to close one end of the cylinder, which usually contains the valves



(Courtesy of Cummins Engine Company, Inc.)

T. Cooling passageway — Hollow space in block through which coolant circulates

U. Oil cooler — Heat exchanger for lowering the temperatures of oil

V. Oil pump — Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

W. Oil pan — Reservoir for engine oil

IV. **Operation of the diesel engine** (Transparency 5)

A. Piston moves up on compression stroke.

   1. Air is trapped in the cylinder causing pressure to rise.

   2. Pressure rise causes high temperature.

B. Piston reaches top dead center.

   1. Fuel is injected into the cylinder.

   2. Hot compressed air ignites the fuel.

   3. Combustion occurs.

C. Combustion creates energy to force the piston down on the power stroke.

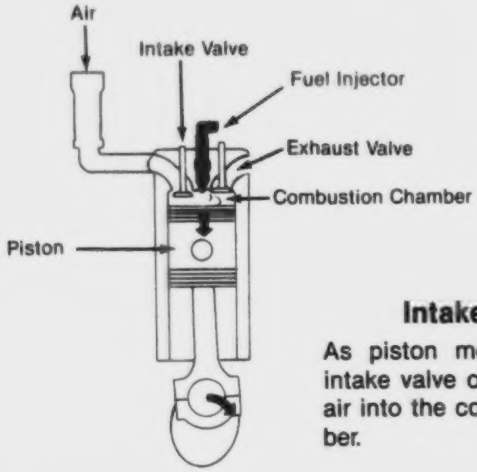
(NOTE: Power is controlled by amount of fuel injected into the cylinder.)

INFORMATION SHEET

V. **Strokes in a four-stroke cycle engine** (Transparency 6)

A. First stroke: Intake

1. Piston moves down.
2. Exhaust valve closes.
3. Intake valve opens.

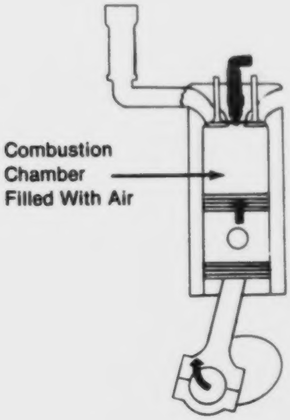

Air
Intake Valve
Fuel Injector
Exhaust Valve
Combustion Chamber
Piston

Intake Stroke

As piston moves down, the intake valve opens and draws air into the combustion chamber.

B. Second stroke: Compression

1. Piston moves up.
2. Intake and exhaust valve close.


Combustion
Chamber
Filled With Air

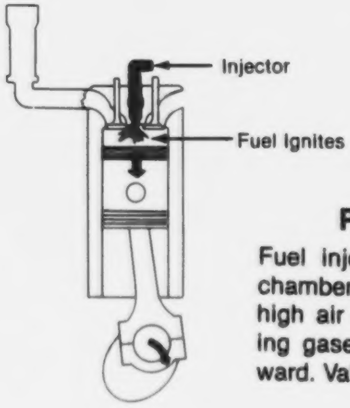
Compression Stroke

Intake and exhaust valves close and seal combustion chamber. Piston moves up and compresses air inside. Air temperature rises.

INFORMATION SHEET

C. Third stroke: Power (ignition)

1. Piston moves down.
2. Intake and exhaust valve close.

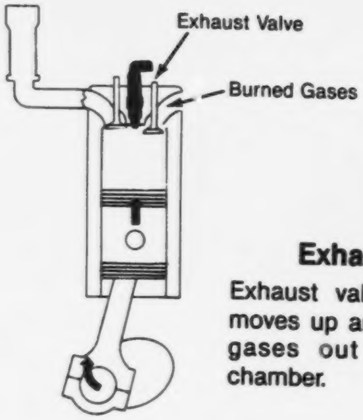

Injector
Fuel Ignites

Power Stroke

Fuel injects into combustion chamber and ignites due to high air temperature. Expanding gases force piston downward. Valves remain closed.

D. Fourth stroke: Exhaust

1. Piston moves up.
2. Intake valve closes.
3. Exhaust valve opens.


Exhaust Valve
Burned Gases

Exhaust Stroke

Exhaust valve opens. Piston moves up and pushes burned gases out of combustion chamber.

INFORMATION SHEET

VI. **Difference between two-stroke cycle and four-stroke cycle engines**

- A. Four-stroke cycle — Fires every other time piston reaches top dead center. (Transparency 6)

  (NOTE: Crankshaft makes two revolutions and piston makes four strokes.)

- B. Two-stroke cycle — Fires each time piston reaches top dead center. (Transparency 7)

  (NOTE: Crankshaft makes one revolution and piston makes two strokes but completes all four events in the cycle. Cylinder has been charged by a blower forcing air through ports near the bottom of the cylinder.)

VII. **Characteristics of two-stroke cycle and four-stroke cycle engines**

- A. Two-stroke cycle
  1. Produces a power stroke for each revolution of the crankshaft.
  2. Theoretically produces twice the power for the same size engine.
  3. Runs smoother since power strokes occur at shorter intervals.
- B. Four-stroke cycle
  1. Has fewer heat problems since each cylinder fires half as often.
  2. Does not use engine power to drive a blower to force air charge into the cylinder under pressure.
  3. Completely clears burned gases from the cylinder, which results in more power per power stroke.
  4. Exhaust valves or ports open later, which creates some gain in effective power.

VIII. **Differences between diesel and gasoline engines**

- A. Fuel ignition
  1. Diesel — Ignition by compression
  2. Gasoline — Ignition by electrical spark
- B. Intake air
  1. Diesel — Takes fresh air directly to combustion chamber
  2. Gasoline — Takes fresh air and fuel through carburetor, then to combustion chamber

INFORMATION SHEET

C. Compression

1. Diesel — High compression ratio (16-22:1)
2. Gasoline — Low compression ratio (7-11:1)

D. Fuel

1. Diesel — Burns low grade fuel oil
2. Gasoline — Burns gasoline

E. Fuel delivery system

1. Diesel — Fuel injected directly into combustion chamber
2. Gasoline — Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber

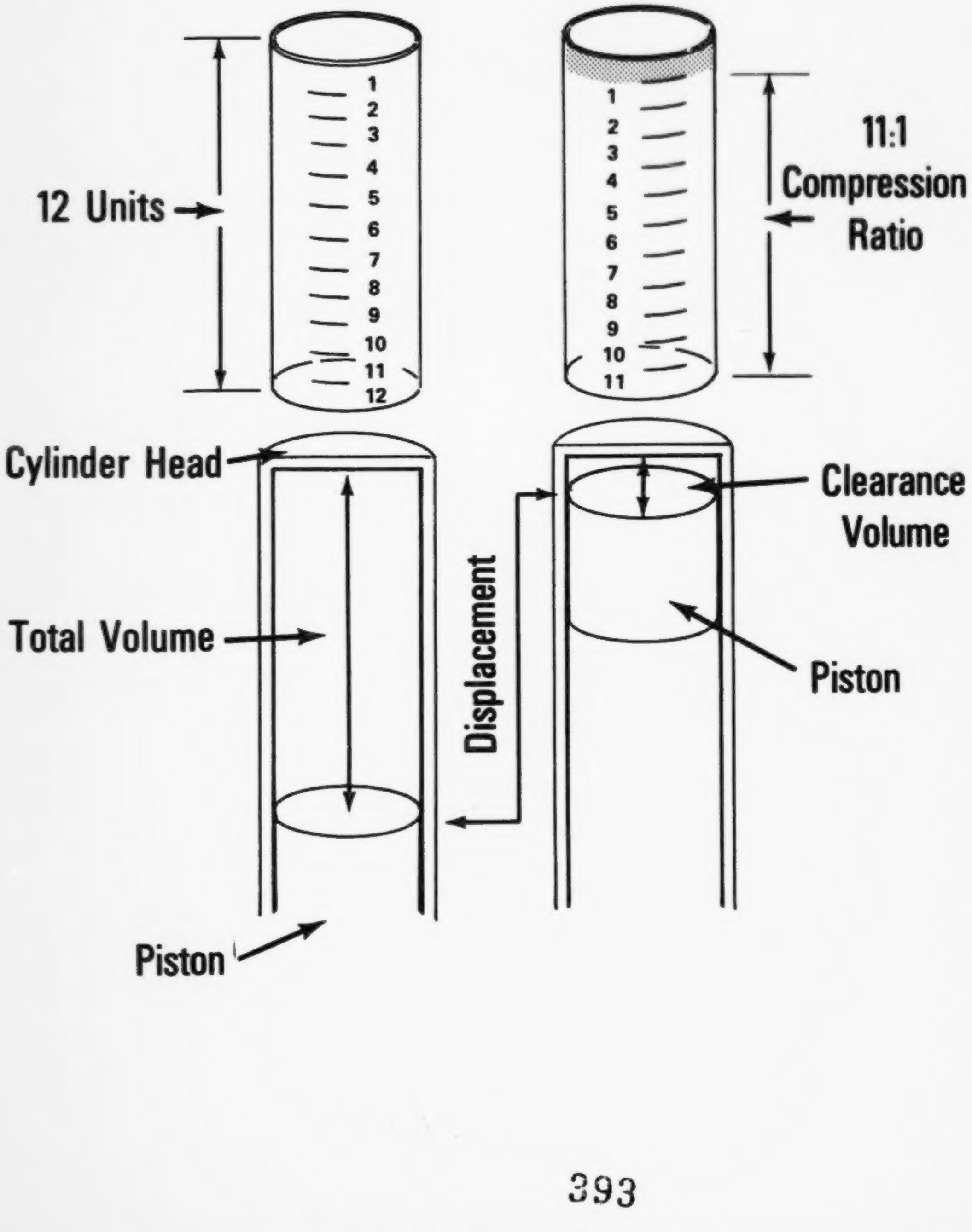
F. Construction

1. Diesel — Heavier construction

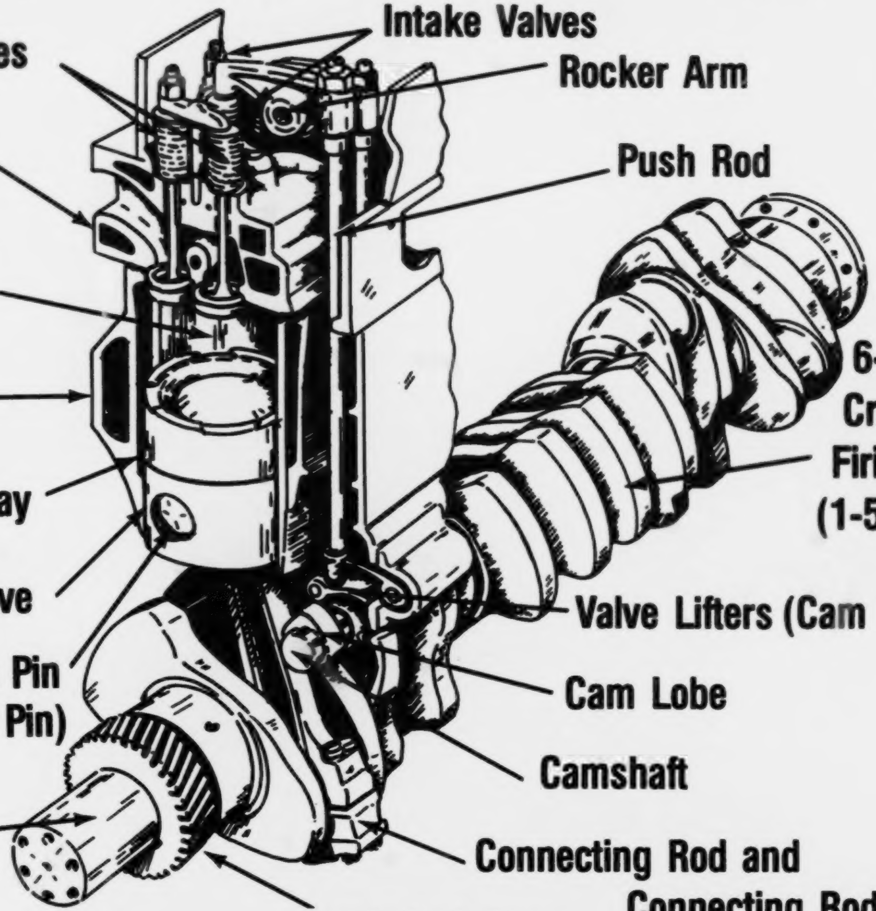
   (NOTE: Heavy construction is required to handle the high pressure and temperature generated in a diesel engine.)

2. Gasoline — Lighter construction

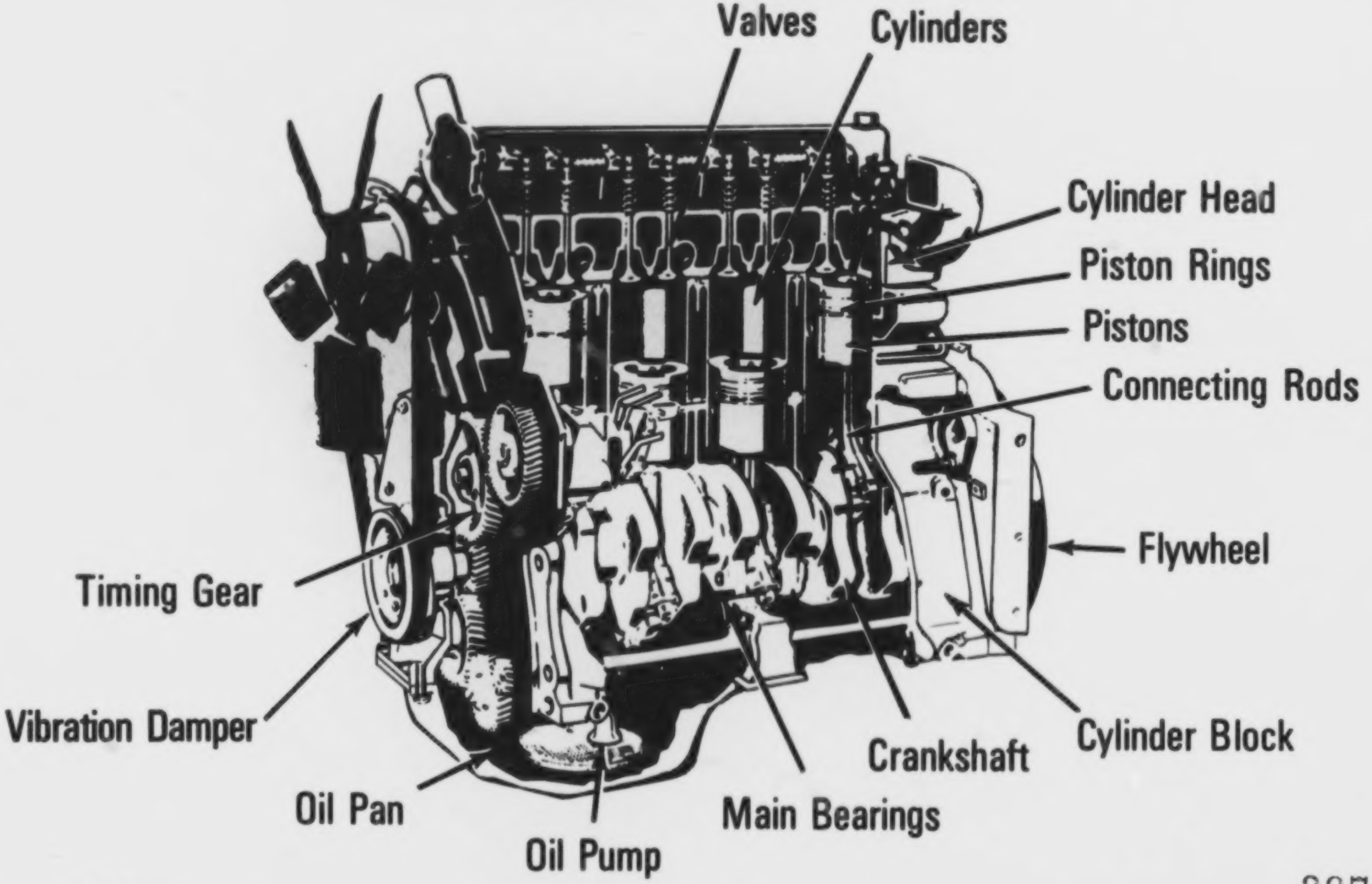
Compression Ratio


12 Units
1
2
3
4
5
6
7
8
9
10
11
12
11:1 Compression Ratio
Cylinder Head
Clearance Volume
Total Volume
Displacement
Piston
Piston

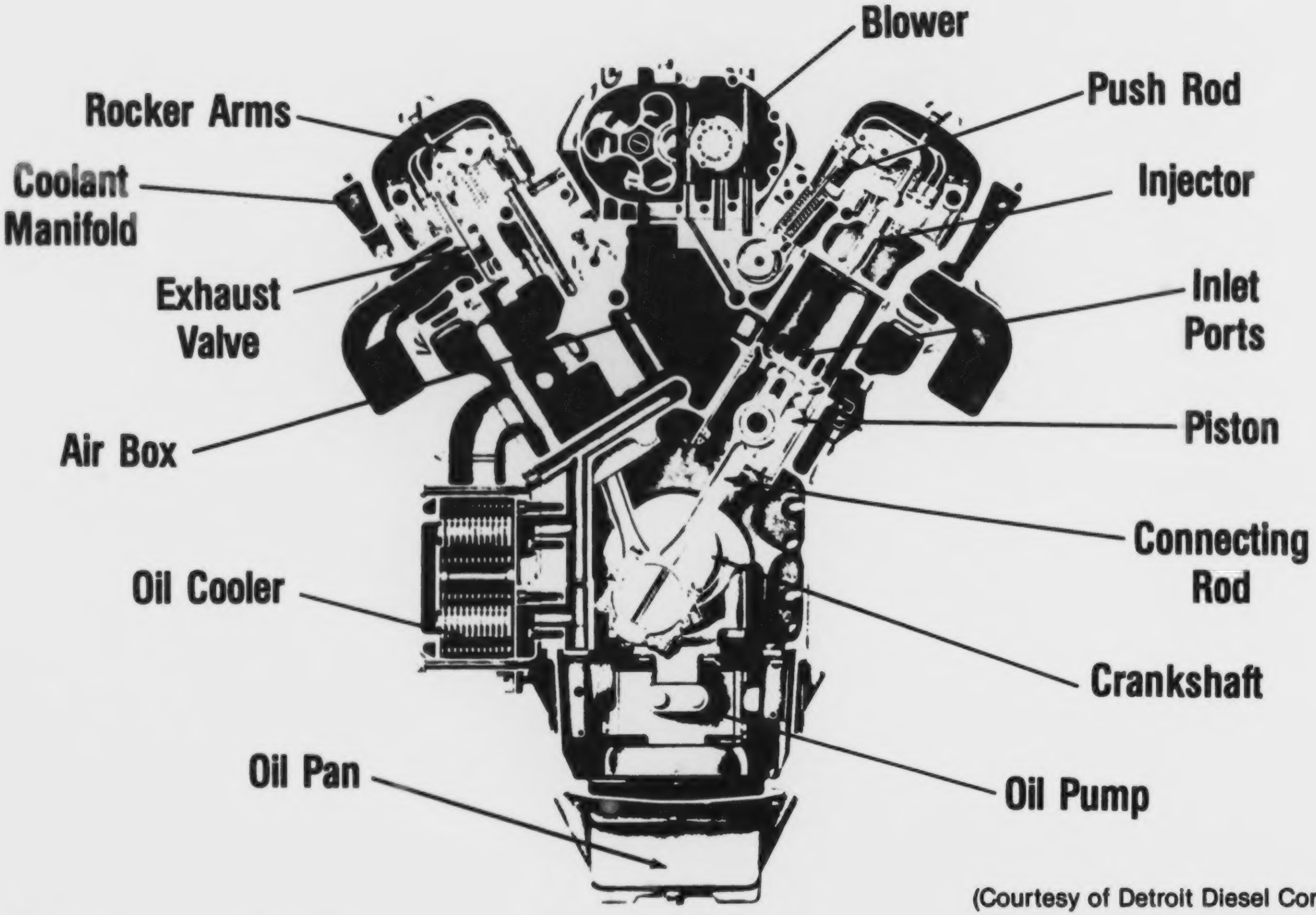
Basic Parts of a Four-Cycle Diesel Engine


Intake Valves
Exhaust Valves
Rocker Arm
Cylinder Head
Push Rod
Open Combustion Chamber
6-Cylinder Crankshaft
Cylinder Block
Firing Order (1-5-3-6-2-4)
Cooling Passageway
Wet Type Sleeve
Valve Lifters (Cam Followers)
Piston Pin (Wrist Pin)
Cam Lobe
Camshaft
Crankshaft
Connecting Rod and Connecting Rod Bearings
Crankshaft Gear

Basic Internal Engine Parts

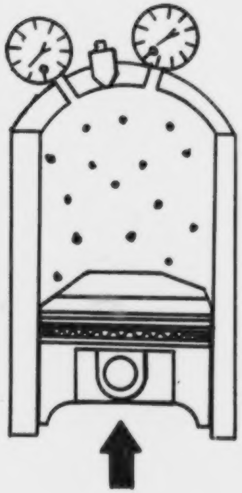

Valves
Cylinders
Cylinder Head
Piston Rings
Pistons
Connecting Rods
Flywheel
Timing Gear
Vibration Damper
Cylinder Block
Crankshaft
Oil Pan
Main Bearings
Oil Pump

Basic Parts of a Two-Cycle Diesel Engine

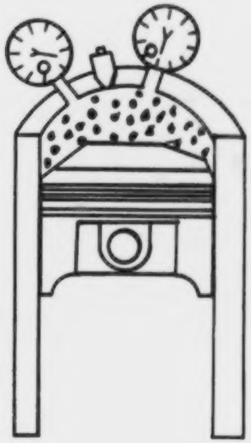

Blower
Rocker Arms
Push Rod
Coolant Manifold
Injector
Exhaust Valve
Inlet Ports
Air Box
Piston
Connecting Rod
Oil Cooler
Crankshaft
Oil Pan
Oil Pump

(Courtesy of Detroit Diesel Corporation)

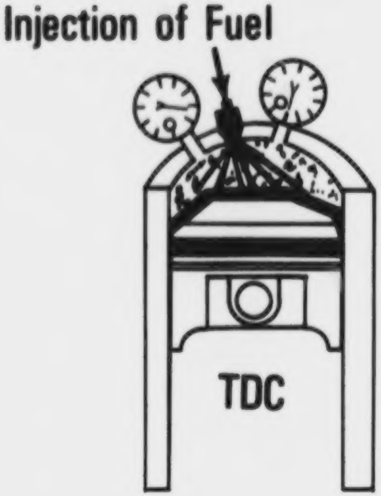
Diesel Engine Combustion



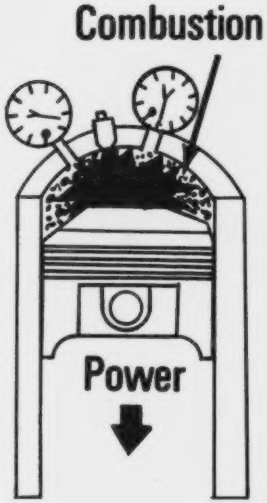
Piston moves up on compression stroke



Air is trapped in the cylinder causing pressure to rise

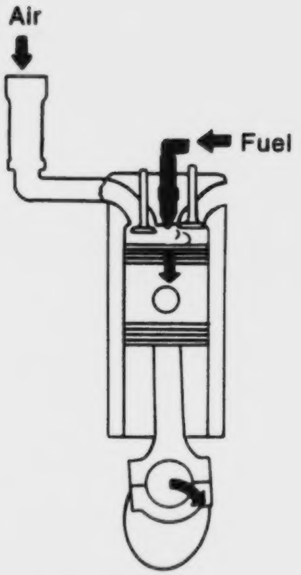

Injection of Fuel
TDC

Piston reaches TDC and fuel is injected into the cylinder


Combustion
Power

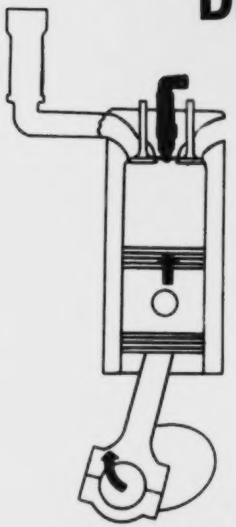
Hot compressed air ignites the fuel, combustion occurs, and this creates energy to force the piston down on the power stroke

Four-Stroke-Cycle Diesel Engine



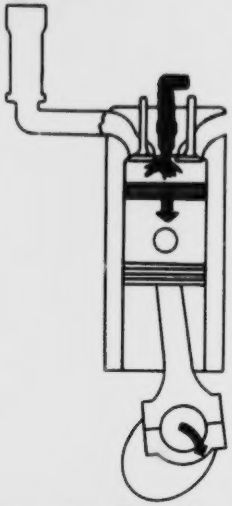
Intake Stroke

Air mixture is drawn or forced into combustion chamber. Intake valve is open.



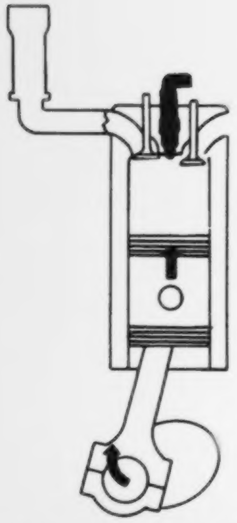
Compression Stroke

Air is compressed by upstroke of piston. Both intake and exhaust valves are closed.



Power Stroke

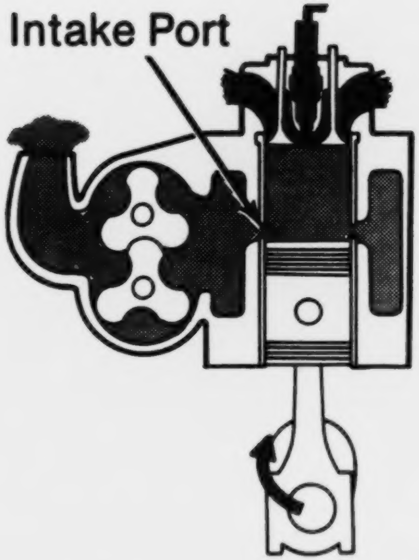
Temperature of air is raised due to high compression, which causes fuel to ignite as it is sprayed (injected) into combustion chamber. Expanding gases force piston to bottom of cylinder. Valves remain closed.



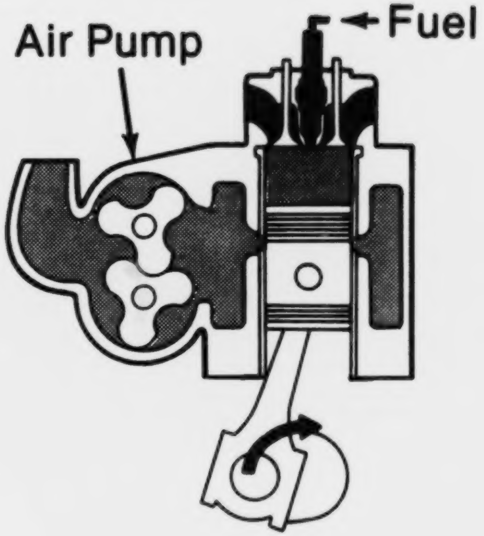
Exhaust Stroke

Piston on upstroke forces burned gases from cylinder through open exhaust valve.

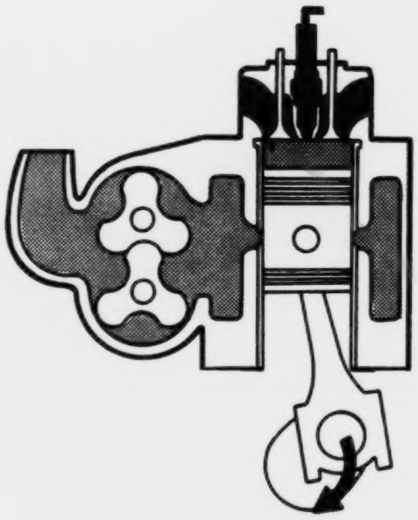
Two-Stroke-Cycle Diesel Engine


Intake Port

Intake and Exhaust


Air Pump
Fuel

Compression Stroke



Power Stroke

TM 7

D-31-B

ENGINE OPERATING PRINCIPLES
UNIT I-B

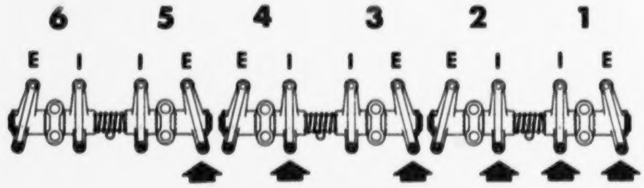
ASSIGNMENT SHEET #1 — LOCATE INTAKE AND EXHAUST VALVES ON AN ENGINE

NAME ______________________________ SCORE ____________

The best way to locate the position of the valves on an engine is to check with the service manual. The reason a mechanic needs to know the location of the intake or exhaust valves is to aid in adjusting a valve, timing an engine, or placing an engine on TDC #1 compression.

The service manual will give the specifications as in the example.

Example:



No. 1 TDC Compression Stroke
Valve Arrangement

(Courtesy of J. I. Case Co.)

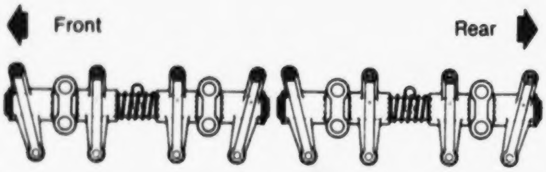
(NOTE: This is just an example and may not apply to the engine you are working on.)

Some service manuals may not give the specifications; then the mechanic has to determine the intake or exhaust valve. If the service manual does not give the specification for the engine you are working on, ask your instructor what method to use to determine intake or exhaust valve.

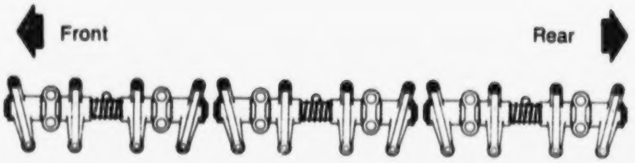
Look in a service manual corresponding to the engine you are working on, and write the arrangement of the valves. Number the valves in order from front to rear and write which valve is intake or exhaust. Using the illustrations on the next page, write your valve arrangement in the proper format for the engine you are working on.

ASSIGNMENT SHEET #1

FOUR CYLINDER ENGINE

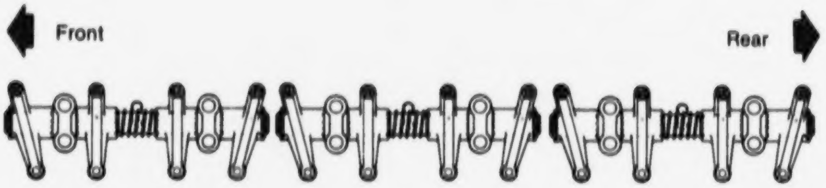


SIX CYLINDER ENGINE

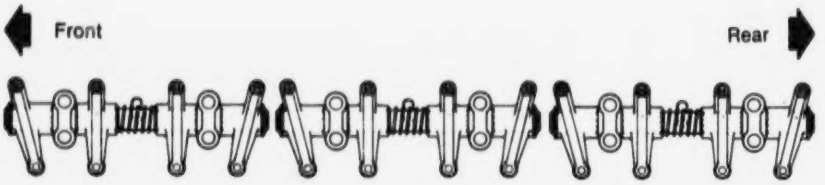


V SERIES ENGINE

(NOTE: This applies to V6, V8, or V12 engines.)



Right Bank



Left Bank

Obtain instructor's initials here ___________.

ENGINE OPERATING PRINCIPLES
UNIT I-B

ASSIGNMENT SHEET #2 — LOCATE TDC #1 CYLINDER ON COMPRESSION STROKE OF AN ENGINE

NAME ______________________________ SCORE __________

Often a mechanic is required to place an engine on TDC #1 compression to adjust the valves, install an injection pump, or check the timing of the engine. With all the different types of engines on the market, it is recommended that you try to obtain the service manual for the specific engine you work on. Sometimes the correct manual is not available, so it is up to the mechanic to put #1 cylinder on TDC. There are several general methods to use. This assignment sheet covers two methods; your instructor may have additional ones. These methods may be used for a six-cylinder in-line engine.

Method #1

1. Locate timing marks on the engine (vibration damper or on the flywheel).

   (NOTE: Some engines may not have marks but will have a pin that drops into a slot when at TDC. The only problem is that you don't know if you are TDC #1 or #6.)

2. Remove valve cover from the engine.

3. Rotate engine in the correct direction of rotation while watching intake valve rocker arm on #1 cylinder.

   (CAUTION: Be sure the fuel system is in the no-fuel (kill) position to prevent engine from starting.)

4. While rotating engine, watch intake valve go down (open), come back up, and stop (closed).

5. Keep rotating engine and watch for timing mark to align with mark on vibration damper or flywheel.

   (NOTE: The pin drops into the slot.)

6. When the marks align, the engine is at TDC #1.

Method #2

Use this method to arrive at approximate TDC #1 when there is no timing mark or service manual available.

1. Remove valve cover from the engine.

ASSIGNMENT SHEET #2

2. Rotate engine in direction of proper rotation while watching the intake valve rocker arm on #1 cylinder.

   (CAUTION: Keep engine from starting while rotating.)

3. While rotating engine, watch intake valve go down (open), come back up, and stop (closed).

4. Keep rotating engine and watch #6 exhaust valve (mating cylinder to #1); it will be down (open).

5. Rotate engine until #6 valve comes up and stops (closed).

6. The engine is at approximately TDC #1.

For your assignment, go into the shop and position an engine on TDC #1 compression stroke by using the method outlined above.

Obtain your instructor's initials here _____________.

If your shop has a manual corresponding to the engine you are working on, check to see if the methods are near the manual specifications.

Ask your instructor to suggest other possible methods of putting an engine on TDC #1 compression stroke.

ENGINE OPERATING PRINCIPLES
UNIT I-B

NAME ____________________ SCORE ____________________

TEST

1. Match the terms related to engine operating principles with the correct definitions.

_____a. Total space between the piston at its lowest position in the cylinder and the bottom of the cylinder head

_____b. Total space between the cylinder head and the piston when the piston is at its highest position in the cylinder

_____c. The reduction in volume of gases trapped in the cylinder caused by the upward motion of the piston

_____d. Ratio of whole cylinder volume to least cylinder volume

_____e. Ignition of the fuel by the heat of compression

_____f. Measure of heat intensity

_____g. Action or operation of burning

_____h. Cavity in the cylinder head of some diesels where some burning of fuel first takes place

_____i. Piston at highest point of travel

_____j. Piston at lowest point of travel

_____k. Distance the piston moves when traveling from TDC to BDC

_____l. Crankshaft revolutions per minute

_____m. Controlling the engine power by varying or governing the amount of fuel injected into the combustion chamber

_____n. Surface shape of the top of the piston

_____o. Series of events that repeat themselves in a regular sequence

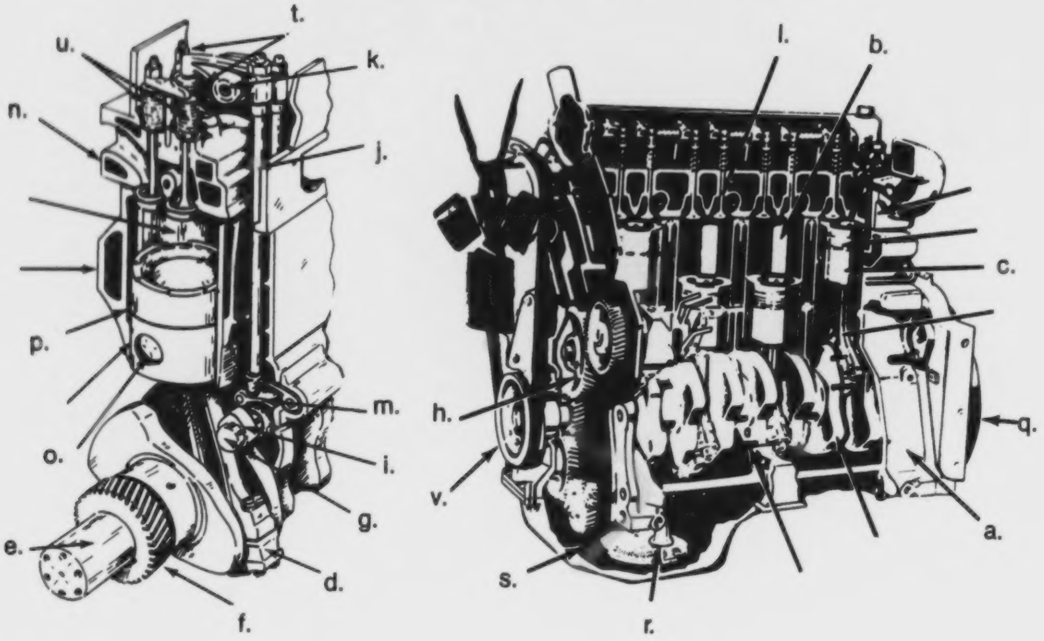
_____p. The displacement of exhaust gas from the cylinder by fresh air

_____q. Period of crankshaft rotation during which both intake and exhaust valves are open

1. BDC
2. Clearance volume
3. Combustion
4. Compression
5. Compression ignition
6. Compression ratio
7. Cycle
8. Engine speed
9. Piston crown
10. Power control
11. Pre-combustion chamber
12. Scavenging
13. Stroke
14. TDC
15. Temperature
16. Valve overlap
17. Volume

TEST

2. Identify any fifteen of the following basic parts of a diesel engine.


t.
u.
k.
n.
j.
l.
b.
c.
p.
m.
h.
q.
i.
o.
v.
g.
a.
e.
d.
s.
f.
r.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

f. ______________________

g. ______________________

h. ______________________

i. ______________________

j. ______________________

k. ______________________

l. ______________________

m. ______________________

n. ______________________

o. ______________________

p. ______________________

q. ______________________

r. ______________________

s. ______________________

t. ______________________

u. ______________________

v. ______________________

TEST

3. Match the basic diesel engine parts with the correct functions.

_____a. Solid casing which includes the cylinders and water jackets

_____b. Holes in the cylinder block containing the pistons

_____c. Movable plugs open at one end which transfer force of explosion to the connecting rod

_____d. Connecting link between the piston and crankshaft

_____e. Main shaft of an engine which, turned by the connecting rods, changes the reciprocating motion of the piston to the rotary motion in the power train

_____f. Drives the camshaft or idler gear

_____g. Shaft with cam lobes used to operate the valves

_____h. A gear attached to the crankshaft that drives the camshaft; regulates speed and performance

_____i. Eccentrics on the camshaft that operate the valves

_____j. Rod links that transfer motion from the lifter to the rocker arm

_____k. Transfers motion from push rod to valve to open the valve

_____l. Rides on the camshaft so that the cam lobe raises it to operate the valve

_____m. Opens and allows exhaust gases to be forced from engine cylinder

_____n. Metal section bolted to the block to close one end of the cylinder, which usually contains the valves

_____o. Provides pressure that circulates oil to rotating or reciprocating engine parts to minimize friction

1. Cam lobes
2. Camshaft
3. Connecting rod
4. Cooling passageway
5. Crankshaft
6. Crankshaft gear
7. Cylinder block
8. Cylinder head
9. Cylinders
10. Exhaust valve
11. Flywheel
12. Intake valve
13. Oil cooler
14. Oil pan
15. Oil pump
16. Piston pin
17. Pistons
18. Push rods
19. Rocker arm
20. Timing gear
21. Valve lifter
22. Valves
23. Vibration damper

TEST

______p. Serves as floating connecting piece for piston and connecting rod

______q. Hollow space in block through which coolant circulates

______r. Reservoir for engine oil

______s. Permits air to enter the cylinder

______t. Open and close the cylinder to allow air to enter or gases to leave the cylinder

______u. A specially designed device mounted to the front of the crankshaft to reduce torsional vibration

______v. Attaches to the end of the crankshaft and provides inertia to carry the crankshaft around from one firing impulse to the other

______w. A heat exchanger for lowering the temperatures of oil

4. Arrange in order the sequence of the operation of the diesel engine by placing the correct sequence number in the appropriate blank.

______a. Piston reaches top dead center.

1) Fuel is injected into the cylinder.
2) Hot compressed air ignites the fuel.
3) Combustion occurs.

______b. Combustion creates energy to force the piston down on the power stroke.

______c. Piston moves up on compression stroke.

1) Air is trapped in the cylinder causing pressure to rise.
2) Pressure rise causes high temperature.

5. Complete the following list of what happens during each stroke of a four-stroke cycle engine.

a. First stroke: Intake

1) Piston moves down.

2) Exhaust valve closes.

3) ____

TEST

b. Second stroke: Compression

1) ____________________

2) Intake and exhaust valve close.

c. Third stroke: Power

1) ____________________

2) Intake and exhaust valve close.

d. Fourth stroke: Exhaust

1) Piston moves up.

2) ____________________

3) Exhaust valve opens.

6. Differentiate between two-stroke cycle and four-stroke cycle engines by placing an "X" next to the description of a four-stroke cycle.

_____a. Fires every other time piston reaches top dead center

_____b. Fires each time piston reaches top dead center

7. Differentiate between the characteristics of two-stroke cycle and four-stroke cycle engines by placing an "X" next to the characteristics of a two-stroke cycle engine.

_____a. Does not use engine power to drive a blower to force air charge into the cylinder under pressure

_____b. Produces a power stroke for each revolution of the crankshaft

_____c. Has fewer heat problems since each cylinder fires half as often

_____d. Exhaust valves or ports open later, which creates some gain in effective power

_____e. Theoretically produces twice the power for the same size engine

_____f. Runs smoother since power strokes occur at shorter intervals

_____g. Completely clears burned gases from the cylinder, which results in more power per power stroke

TEST

8. Differentiate between diesel engines and gasoline engines by placing an "X" next to the descriptions of diesel engines.

_____a. Ignition by compression

_____b. Burns gasoline

_____c. Lighter construction

_____d. High compression ratio

_____e. Heavier construction

_____f. Takes fresh air directly to combustion chamber

_____g. Ignition by electrical spark

_____h. Low compression ratio

_____i. Burns low grade fuel oil

_____j. Fuel and air mixture drawn through carburetor and intake manifold into combustion chamber

_____k. Takes fresh air and fuel through carburetor then to combustion chamber

_____l. Fuel injected directly into combustion chamber

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Locate intake and exhaust valves on an engine. (Assignment Sheet #1)

10. Locate TDC #1 cylinder on compression stroke of an engine. (Assignment Sheet #2)

ENGINE OPERATING PRINCIPLES
UNIT I-B

ANSWERS TO TEST

1.	a.	17	g.	3	m.	10
	b.	2	h.	11	n.	9
	c.	4	i.	14	o.	7
	d.	6	j.	1	p.	12
	e.	5	k.	13	q.	16
	f.	15	l.	8		

2. Any fifteen of the following:

   a. Cylinder block
   b. Cylinders
   c. Pistons
   d. Connecting rod
   e. Crankshaft
   f. Crankshaft gear
   g. Camshaft
   h. Timing gear
   i. Cam lobes
   j. Push rods
   k. Rocker arm
   l. Valves
   m. Valve lifter
   n. Cylinder head
   o. Wrist pin or piston pin
   p. Cooling passageway
   q. Flywheel
   r. Oil pump
   s. Oil pan
   t. Intake valve
   u. Exhaust valve
   v. Vibration damper

3.	a.	7	i.	1	q.	4
	b.	9	j.	18	r.	14
	c.	17	k.	19	s.	12
	d.	3	l.	21	t.	22
	e.	5	m.	10	u.	23
	f.	6	n.	8	v.	11
	g.	2	o.	15	w.	13
	h.	20	p.	16		

ANSWERS TO TEST

4. a. 2
   b. 3
   c. 1

5. a. Intake valve opens
   b. Piston moves up
   c. Piston moves down
   d. Intake valve closes

6. a

7. b, e, f

8. a, d, e, f, i, l

9.-10. Evaluated to the satisfaction of the instructor

CYLINDER HEAD ASSEMBLY
UNIT II-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to disassemble, inspect, service, and assemble a cylinder head and its parts. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to a cylinder head with the correct definitions.
2. Select major parts usually found in a cylinder head assembly.
3. Identify forms of cylinder head castings that may be found on a diesel engine.
4. Identify the primary parts of a valve assembly.
5. List types of valve rotators.
6. Identify types of valve arrangement.
7. List locations for turbulence chambers in an engine.
8. Identify forms of engine valves.
9. Name three factors determining cylinder head size.
10. Demonstrate the ability to:
    a. Remove, inspect, and install a cylinder head. (Job Sheet #1)

OBJECTIVE SHEET

b. Disassemble and service a valve train. (Job Sheet #2)

c. Service valve guides. (Job Sheet #3)

d. Grind valve seats. (Job Sheet #4)

e. Replace valve seat inserts. (Job Sheet #5)

f. Assemble a cylinder head. (Job Sheet #6)

CYLINDER HEAD ASSEMBLY
UNIT II-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

  1. Have students list the parts in a head assembly.
  2. Demonstrate different valve angles.
  3. Show various valve designs.
  4. Demonstrate testing valves and seats for leaks.
  5. Show various types of valve seat inserts.
  6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

REFERENCES USED IN DEVELOPING THIS UNIT

B. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

C. *Highway Vehicle Service Manual.* Allentown, PA: Mack Truck, Inc., 1980.

D. Schulz, Erich. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1983.

E. *Service Manual: 92 Series.* Detroit, MI: General Motors Corp., 1985.

F. *Shop Manual.* Columbus, IN: Cummins Engine Company, 1981.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. *Motor Magazine*
Motor Publications
555 West 57th Street
New York, NY 10019
1 800 228-2028

2. *Heads, Valves, and Camshafts*
Literature Order Section
P.O. Box 5319
Morton, IL 61550

B. Filmstrips

1. *Mack 6 Cylinder Engine Rebuild* — Part II
Educational Communications, Inc.
Dept. M
761 Fifth Avenue
King of Prussia, PA 19406

2. *Head and Valve Train.* (Cummins) slides
Literature Control Service
Box 99085
Jeffersontown, KY 40299

3. *Valve Service: Seating and Assembly Procedure.* (Filmstrip with cassette)
Teaching Aids Incorporated
P.O. Box 1798
Costa Mesa, CA 92626-0798
(714) 548-9321

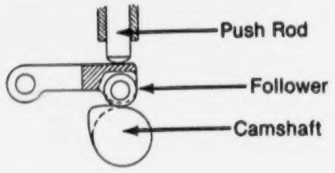
CYLINDER HEAD ASSEMBLY
UNIT II-B

INFORMATION SHEET

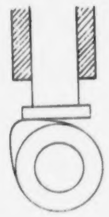
I. **Terms and definitions**

A. Cam follower — Intermediate contact between camshaft and valve stem

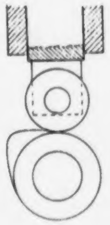
Pivoted Pin Follower with Roller


Push Rod
Follower
Camshaft

Flat or Mushroom Follower



Roller-Type Follower

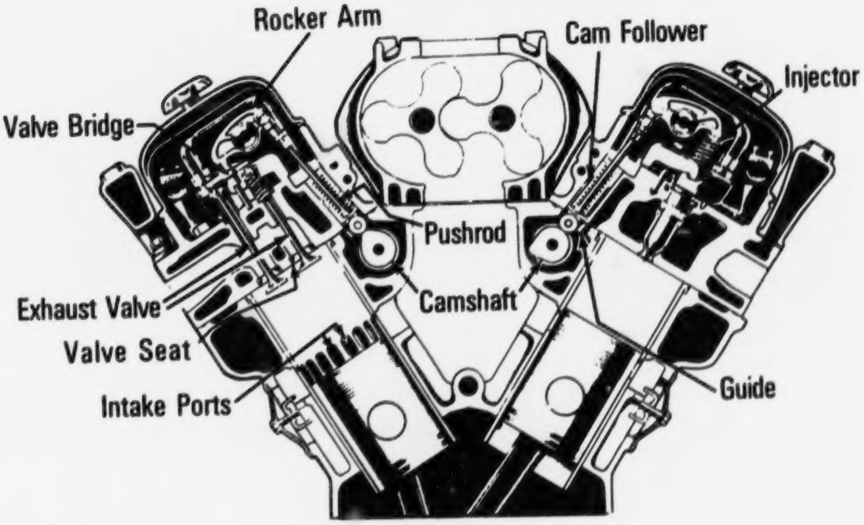


B. Foot-pound — Unit of measure of torque

C. Fuel injection nozzle — Injects fuel under high pressure

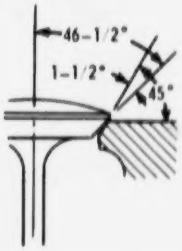
D. Fuel injector — Meters and sprays fuel into the combustion chamber (Transparency 1)

Valve and Fuel Injector


Rocker Arm
Cam Follower
Injector
Valve Bridge
Pushrod
Camshaft
Exhaust Valve
Valve Seat
Intake Ports
Guide

INFORMATION SHEET

E. Interference angle — Permits a narrow leakfree valve seat when the engine is first started; as the valve gets hot, the valve head curls slightly and expands to a full seat contact.



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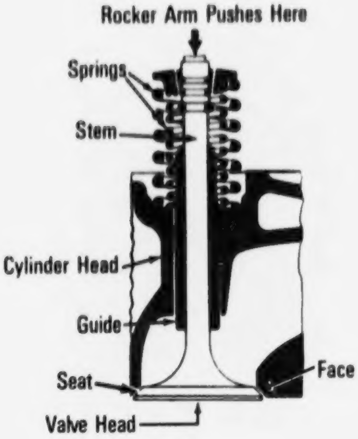
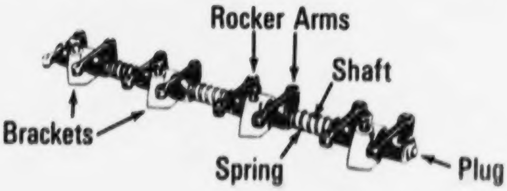
Interference Angle

F. Poppet valve — Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring


Rocker Arm Pushes Here
Springs
Stem
Cylinder Head
Guide
Seat
Face
Valve Head

G. Rocker arm — Lever that transmits the action of the cam to the stem of the valves

H. Rocker arm assembly — Shaft, rocker arm, and cam follower

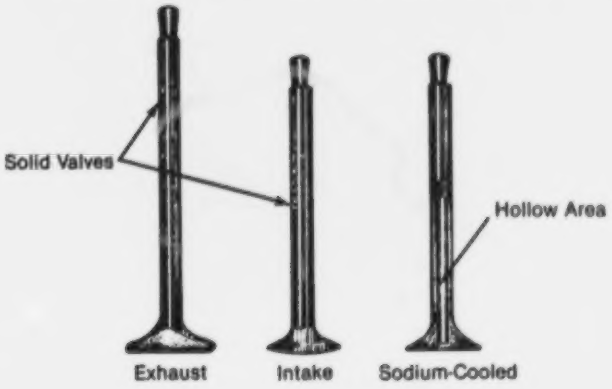

Rocker Arms
Shaft
Brackets
Spring
Plug

INFORMATION SHEET

I. Rocker arm shaft — Serves as a fulcrum for rocker arms

J. Service — To clean, inspect, lubricate, and/or adjust

K. Sodium filled valves — Valves which have been hollowed and partially filled with metallic sodium to reduce valve-head temperature


Solid Valves
Hollow Area
Exhaust
Intake
Sodium-Cooled

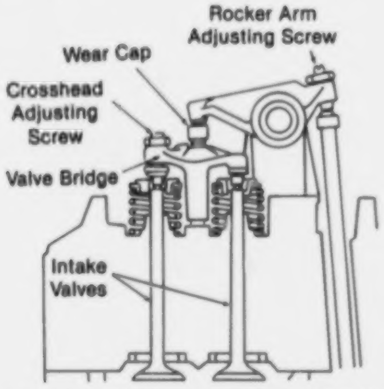
(CAUTION: For disposal of the sodium valve check with your local environmental agency.)

L. Torque — A twisting effort

M. Torque wrench — Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds

N. Turbulence — High velocity swirling of air within the combustion chamber

O. Valve bridge (crosshead) — Permits two valves in the same cylinder to be opened at the same time


Rocker Arm
Adjusting Screw
Wear Cap
Crosshead
Adjusting
Screw
Valve Bridge
Intake
Valves

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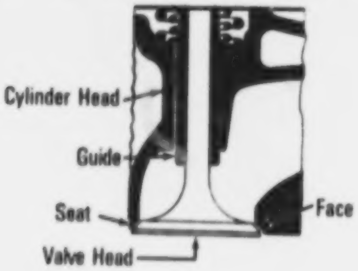
INFORMATION SHEET

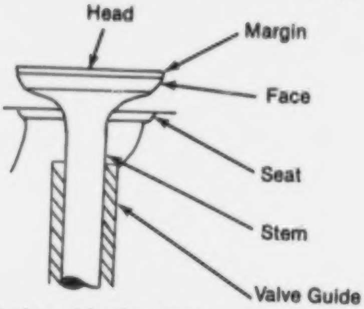
P. Valve face angle — Angle between the valve face and the valve stem

Q. Valve guide — Hole through which the stem of the valve passes

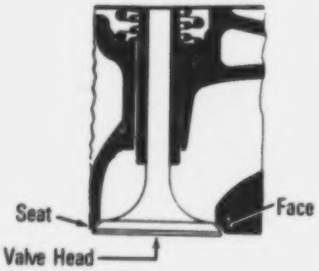
(NOTE: Some guides are pressed into place, and others are drilled into head metal.)


Cylinder Head
Guide
Seat
Face
Valve Head

R. Valve margin — The distance between the edge of the valve and the edge of the face


Head
Margin
Face
Seat
Stem
Valve Guide

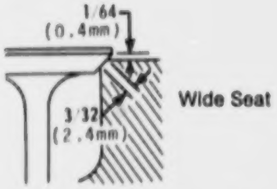
S. Valve seat — That part in the head upon which the valve face rests to close the port

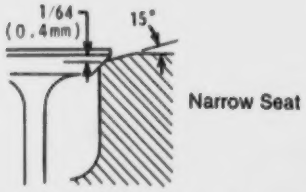

Seat
Face
Valve Head

INFORMATION SHEET

T. Valve seat angle — Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

(NOTE: Some manufacturers recommend interference fit of 29 or 44 degrees.)


1/64
(0.4mm)
3/32
(2.4mm)
Wide Seat


1/64
(0.4mm)
15°
Narrow Seat

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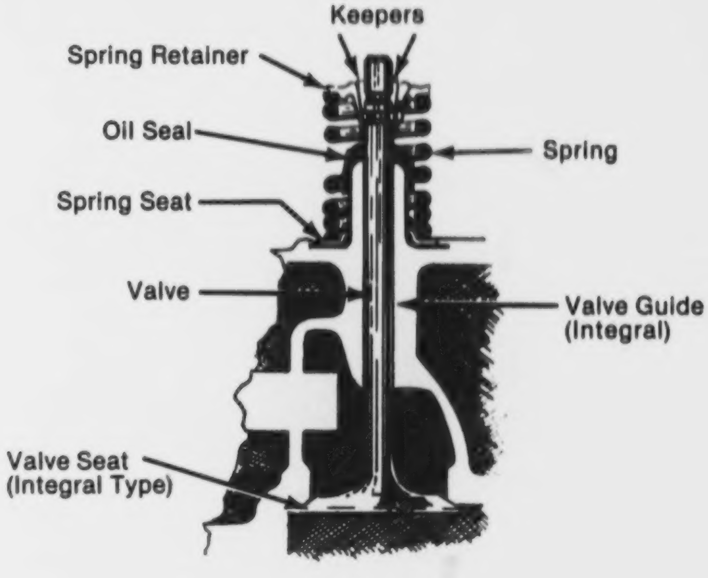
U. Valve spring — Helical spring used to close the valve

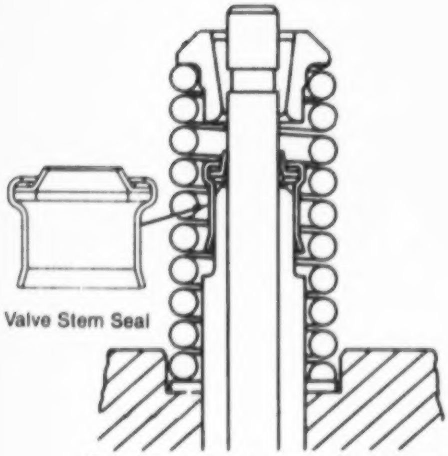
V. Valve spring retainers — Hold the valve spring on the valve stem

(NOTE: This is sometimes called valve spring keeper.)


Keepers
Spring Retainer
Oil Seal
Spring
Spring Seat
Valve
Valve Guide (Integral)
Valve Seat (Integral Type)

INFORMATION SHEET

W. Valve stem seal — Sealing device which prevents excess oil from entering the area between the stem and the valve guide



(Courtesy of Detroit Diesel Corporation.)

II. **Major parts usually found in a cylinder head assembly** (Transparency 1)

A. Intake valve

B. Exhaust valve

C. Rocker arm

D. Fuel injector or nozzle

E. Cam followers (Detroit)

F. Fuel injector tube

G. Valve guides

H. Valve seats

I. Crossheads (valve bridge)

J. Crosshead guides

INFORMATION SHEET

III. **Forms of cylinder head castings**

A. Single

(NOTE: This covers one cylinder.)

B. Multiple

(NOTE: This covers two or more cylinders.)

INFORMATION SHEET

C. One piece

(NOTE: This covers all cylinders.)

IV. **Primary parts of a valve assembly** (Transparency 2)

A. Split collar retainers (valve keepers)

B. Valve spring cup

C. Valve spring

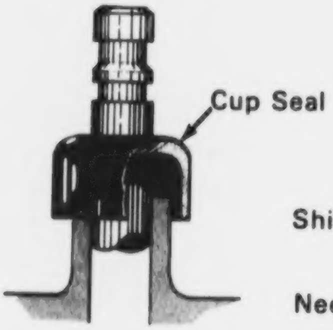
(NOTE: When valve spring has closely-wound coils at one end, place this end toward the cylinder head.)

D. Valve

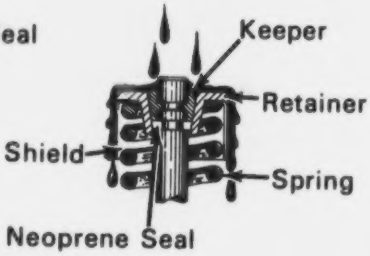
E. Valve stem seal

(NOTE: These seals could be an O-ring or umbrella type.)

Cup or Umbrella



O-Ring


Keeper
Retainer
Shield
Spring
Neoprene Seal

INFORMATION SHEET

V. **Types of valve rotators** (Transparency 3)

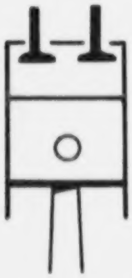
  A. Release type

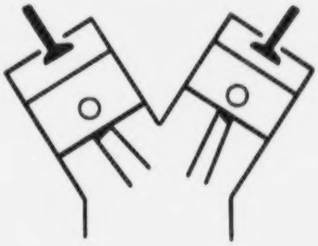
  B. Positive type

VI. **Typical valve arrangements**

  A. I-Head — Both valves above cylinder

  B. H-Head — Both valves above angled cylinders (V-block)

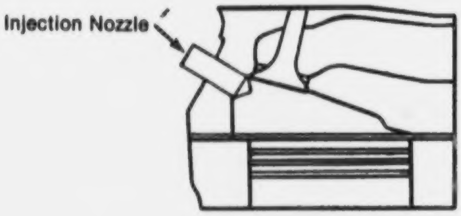

I-Head


H-Head

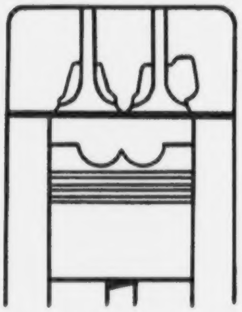
VII. **Locations of turbulence chambers**

  A. Chamber in cylinder head

  B. Chamber in piston



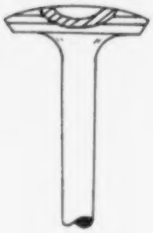
Turbulence Chamber in Cylinder Head


Turbulence Chamber in Top of Piston

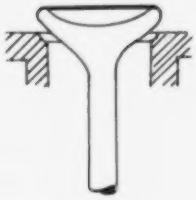
INFORMATION SHEET

VIII. Types of valves

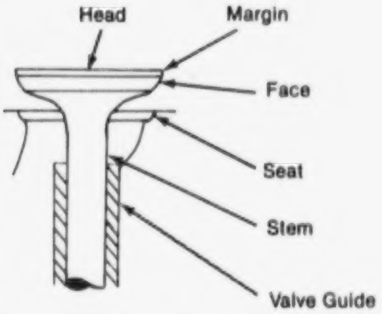
A. Standard



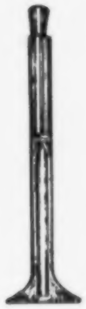
B. Tulip



C. Flat-top


Head
Margin
Face
Seat
Stem
Valve Guide

D. Sodium-filled



IX. Factors determining cylinder head size

A. Cylinder block design

B. Number of main bearings

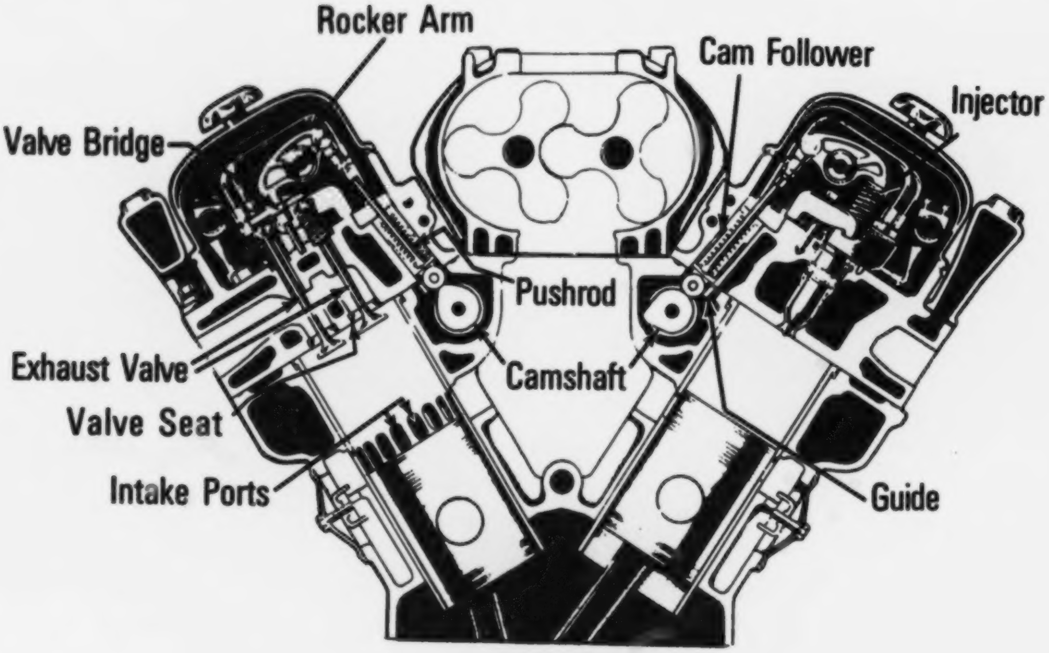
C. Expected thermal stress

D. Cooling and sealing difficulties of the cylinder head

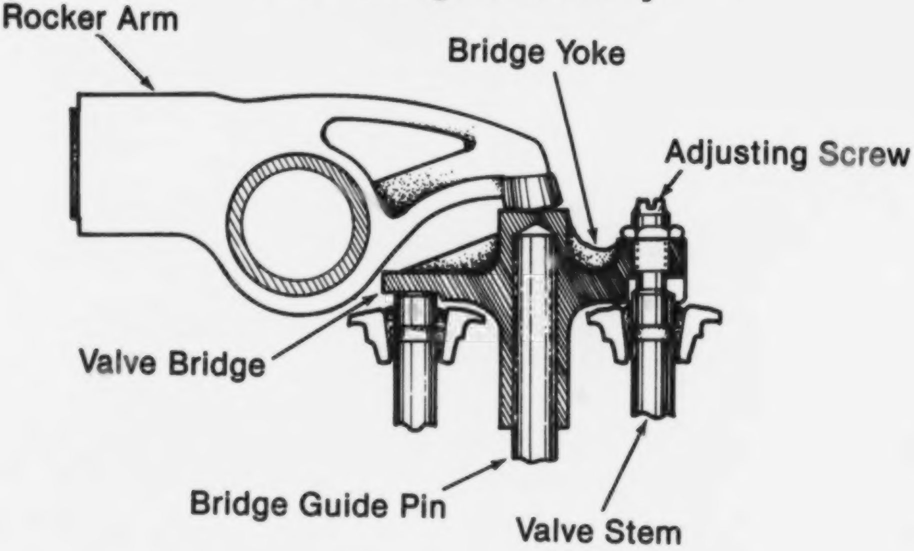
E. The design of the intake and exhaust ports

F. Number and size of cylinders

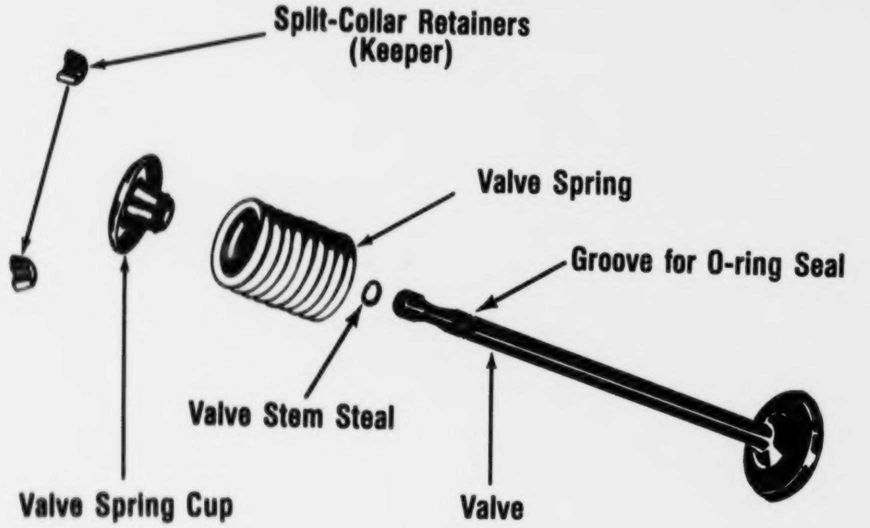
Valve and Fuel Injector


Rocker Arm
Cam Follower
Injector
Valve Bridge
Pushrod
Exhaust Valve
Camshaft
Valve Seat
Intake Ports
Guide

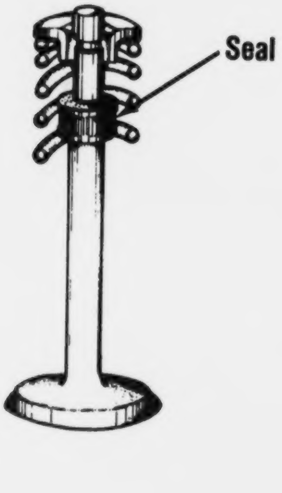
Valve Bridge Assembly


Rocker Arm
Bridge Yoke
Adjusting Screw
Valve Bridge
Bridge Guide Pin
Valve Stem

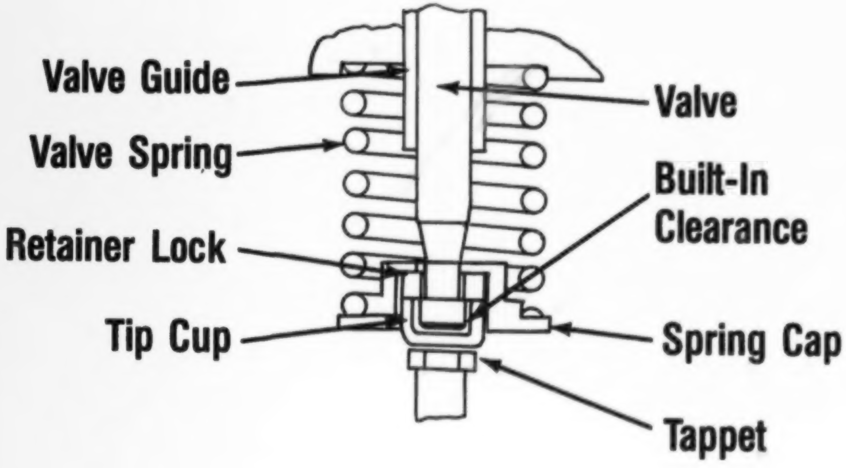
Primary Parts of a Valve Assembly

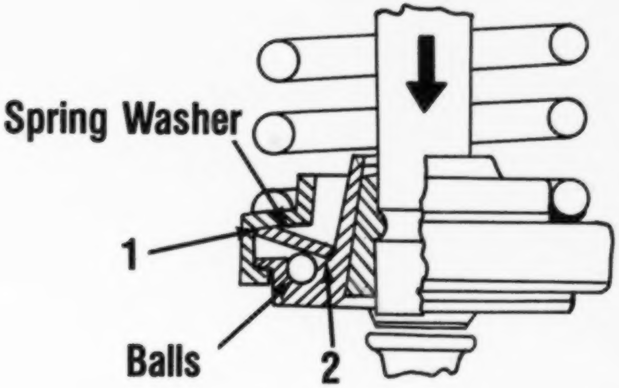

Split-Collar Retainers
(Keeper)
Valve Spring
Groove for O-ring Seal
Valve Stem Steal
Valve Spring Cup
Valve

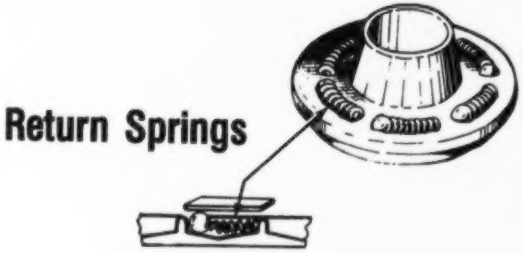
Valve Stem Seal



Valve Rotators


Valve Guide
Valve Spring
Retainer Lock
Tip Cup
Valve
Built-In Clearance
Spring Cap
Tappet


Spring Washer
1
Balls
2


Return Springs

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #1 — REMOVE, INSPECT, AND INSTALL A CYLINDER HEAD

A. Tools and materials

1. Eye protection

   (NOTE: Valve springs are under pressure and wire brush bristles can come loose and damage your eyes.)

2. Shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Steam supply
6. Compressed air supply
7. Chain hoist of sufficient capacity
8. Brass hammer
9. Torque wrench
10. Straightedge
11. Feeler gauge
12. Head gasket scraper
13. Wire brush
14. New head gasket

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove cylinder head.
   - a. Check for oil, water, fuel, or compression leaks around cylinder head.
   - b. Steam clean the engine.
   - c. Drain coolant from engine.

JOB SHEET #1

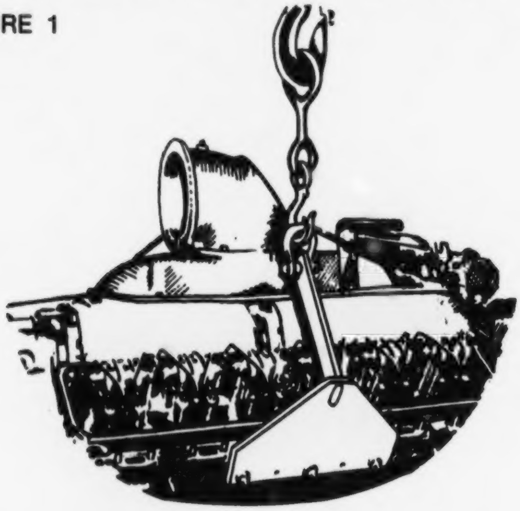
d. Remove accessories attached to cylinder head, allowing a clear place to work.

e. Remove rocker arm cover and rocker arm assembly, if used.

f. Remove cylinder head studs as suggested by manufacturer's specifications.

g. Attach suitable lifting device to head. (Figure 1)

FIGURE 1



h. Break head loose using suitable pry bar and location.

(CAUTION: Do not pry on the contact surfaces.)

i. Place cylinder head in head holding fixture or equivalent and reinstall accessories.)

Obtain instructor's initials here ____________ before proceeding to next step.

2. Inspect cylinder head.

a. Clean the cylinder head and contact surfaces.

b. Clean mating surfaces of the block and head thoroughly.

c. Check for damage to the sealing surfaces of the head or block.

d. Check liner protrusion for proper specification.

e. Clean all carbon deposits from the head by scraping or brushing with a wire brush.

JOB SHEET #1

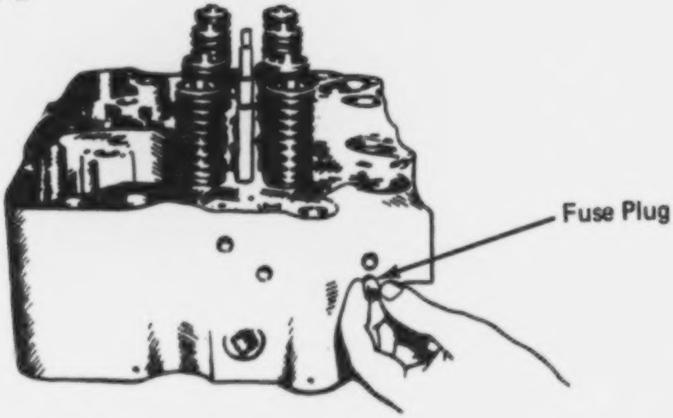
f. Check for lime deposits in water passages and remove soft plug, if used.

(NOTE: Use a recommended solution and dip the head to clean out scale and lime.)

g. Examine fuse plug for signs of overheating. (Figure 2)

(NOTE: Fuse plugs contain a metal alloy center that melts if engine overheats.)

FIGURE 2



h. Inspect and replace soft plug as needed.

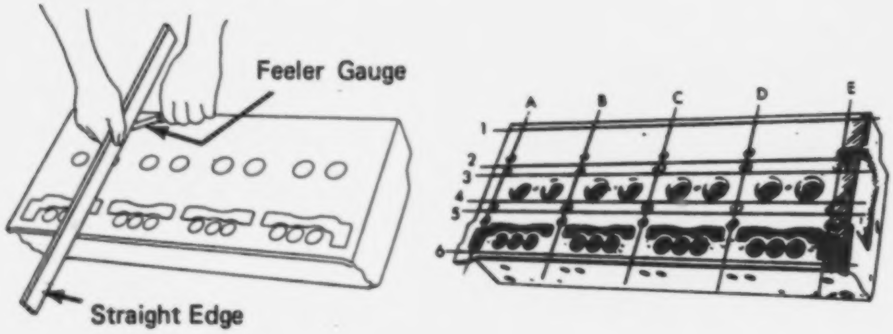
i. Install new plug if metal alloy has melted.

(NOTE: If fuse plug has melted, check carefully for further damage.)

j. Use a heavy straightedge and feeler gauge to check for warpage at each end and between all cylinders.

(NOTE: Also check for end-to-end warpage in at least six places. See Figure 3.)

FIGURE 3



JOB SHEET #1

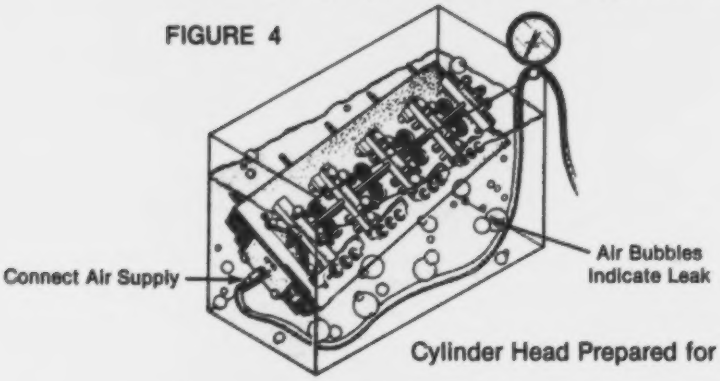
k. Decide whether to reinstall head or reface it.

(NOTE: Consult the engine technical manual for refacing limits.)

l. Check head for leaks or cracks.

1) Water and air pressure method — Seal the head and connect to an air hose. Immerse in hot water (180-200°F) for fifteen minutes. Leaks are detected by any air bubbles which appear in the water. (Figure 4)

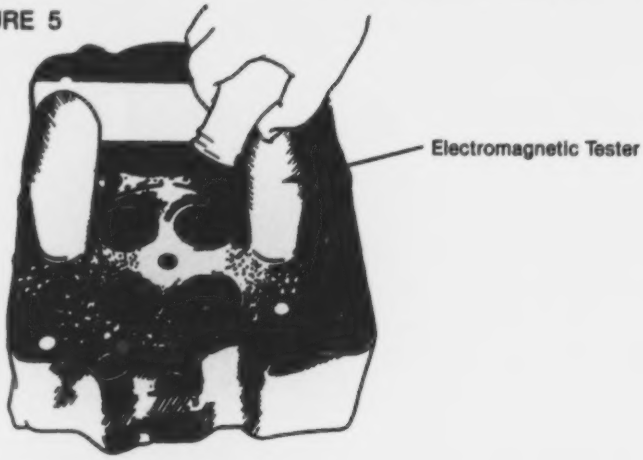
FIGURE 4



Cylinder Head Prepared for Pressure Testing

2) Magnetic crack detector method — Place magnetic crack detector over the suspected area, setting up a magnetic field. (Figure 5)

FIGURE 5



(NOTE: Fine white metallic powder is then sprinkled over the area and the tool is rotated 90 degrees. After excess powder is blown off, any cracks are clearly shown in white.)

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #1

3. Install cylinder head.

   a. Inspect the cylinder head and contact surfaces.

   b. Inspect for scratches or nicks on the sealing surfaces of the head and block.

   c. Inspect and clean cylinder head cap screws and threads.

   d. Install new cylinder head gasket.

   (NOTE: Follow engine manufacturer's or gasket manufacturer's recommendation for applying a sealing compound to one or both sides of the head gasket. Check to be sure that water passage holes are aligned with holes in block. Use aligning dowels if required.)

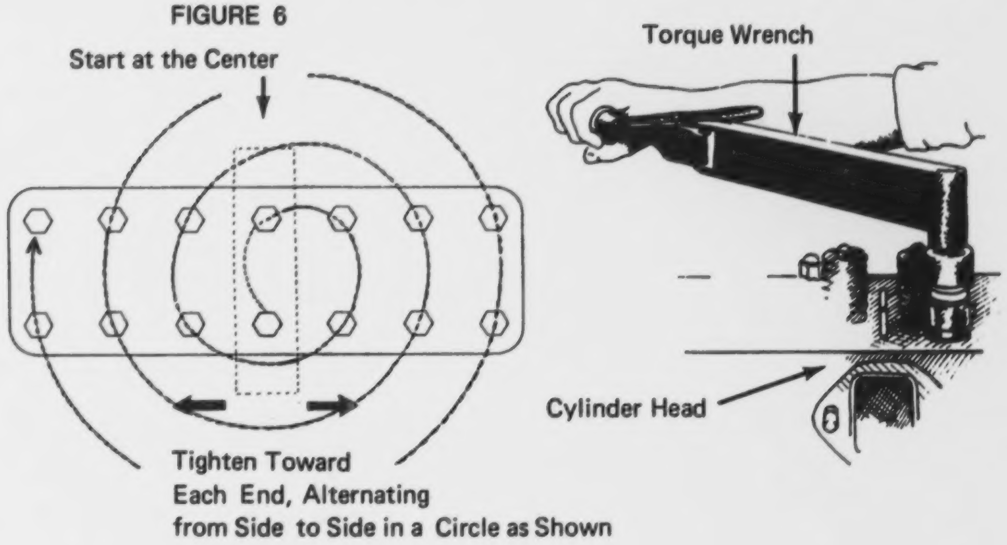
   e. Set head squarely on block without disturbing the head gasket.

   f. Clean and lightly oil bolts or studs.

   g. Start the stud nuts or cap screws and tighten down finger tight.

   h. "Snug" down in the correct sequence (see manufacturer's manual) from center of head out. (Figure 6)

FIGURE 6


Start at the Center
Torque Wrench
Cylinder Head
Tighten Toward Each End, Alternating from Side to Side in a Circle as Shown

   i. Tighten each nut.

   (NOTE: Refer to engine manual for torquing procedures. After the engine has been running a few hours, retighten the stud nuts in the correct sequence with the torque wrench.)

Obtain instructor's initials here ____________.

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #2 — DISASSEMBLE AND SERVICE A VALVE TRAIN

A. Tools and materials

1. Eye protection
2. Appropriate service manual
3. Shop towels
4. Basic hand tool set
5. Board with set of numbered holes for valves
6. Crocus cloth
7. Valve spring compressor
8. Steam supply
9. Compressed air supply
10. Bench grinder
11. 0-1 inch micrometer
12. Valve spring tester
13. Dial indicator

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove valve:
    a. Steam clean complete head assembly.
    b. Dry with compressed air.
    c. Place cylinder head in head holding device or equivalent.

JOB SHEET #2

d. Compress one valve spring at a time with valve compressor. (Figure 1)

FIGURE 1

C-Clamp Valve Spring Compressor

e. Tap valve lightly to loosen; then remove split collar retainers. (Figure 2)

FIGURE 2

f. Remove spring cup.

g. Remove spring.

h. Remove valve stem seal (if used).

i. Remove valve from bottom of cylinder head.

JOB SHEET #2

j. Use a board with a set of numbered holes drilled in it, and place valves in holes in their correct order. (Figure 3)

(CAUTION: Do not mix.)

FIGURE 3

2. Clean valves:

   a. Hold each valve firmly against a wire wheel on a bench grinder, or use glass bead or sandblast method.

   b. Remove all carbon from valve head, face, and stem.

   c. Polish valve stems with crocus cloth.

   (NOTE: Do not use wire brush on stem bearing surface.)

JOB SHEET #2

3. Inspect and test valves.

   a. Inspect valve stems:

      1) Use 0-1 inch micrometer to measure the valve stem. (Figure 4)

      FIGURE 4

(NOTE: Check measurement at various points along the guide bearing surface.)

      2) If diameter is less than specified in manufacturer's manual, discard valve and valve guide.

      (NOTE: See Job Sheet #3 for valve guide replacement.)

   b. Visually check valves:

      1) Check valve for cupped (dished), cracked, or pitted surface.

      2) Check valve margin with the specification.

JOB SHEET #2

3) Check valve stem for nicks, pitting, scuff marks; check keeper (retainer) grooves for damage. (Figure 5)

FIGURE 5

Left to Right: Nicked, Damaged Retainer Grooves, Cupped (Dished), and Eroded Valve Stem.

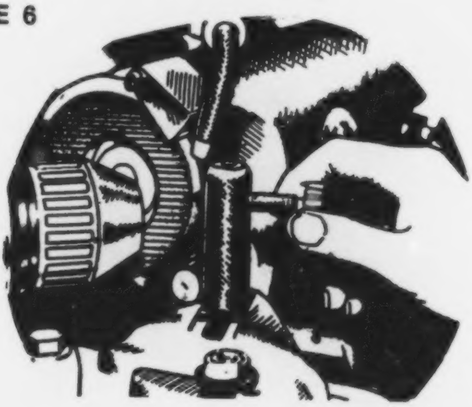
Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #2

4. Reface valves.

   a. Dress wheel, if necessary. (Figure 6)

   FIGURE 6



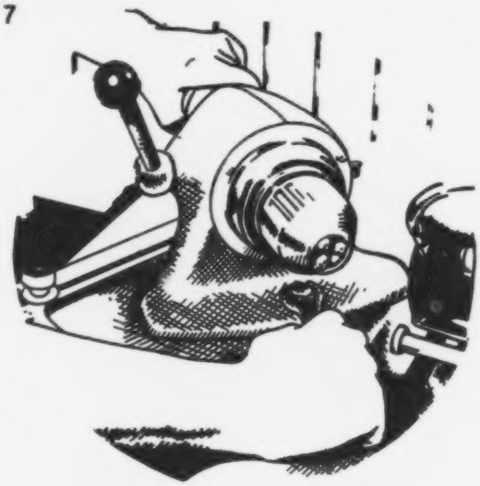
   1) Place dressing attachment against stop bar at slight angle on grinding head, and tighten wing nut.

   2) Turn on motor and take light, steady cuts across wheel.

   (NOTE: Use coolant as required by manufacturer.)

   b. Locate chuckhead. (Figure 7)

   FIGURE 7



   1) Locate chuckhead at the exact angle you wish to refinish valve.

   (NOTE: Refer to manufacturer's specifications for valve face angle, valve seat angle, and interference angle.)

446

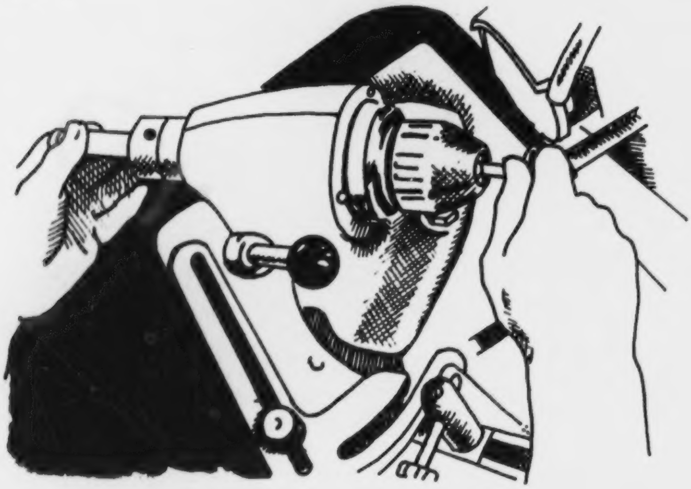
JOB SHEET #2

2) Lock chuckhead with hex nut.

Obtain instructor's initials here ____________ before proceeding to next step.

c. Chuck the valve into valve grinder. (Figure 8)

FIGURE 8



(CAUTION: Special care should be taken when working with sodium-filled exhaust valves.)

1) Open chuck sleeve and insert valve so rollers touch just above the worn part of the stem.

2) Set aligner for proper length of valve.

3) Close chuck sleeve to contact stem.

4) Depress lever and close chuck sleeve about 1/8 turn.

(NOTE: Use according to manufacturer's specifications.)

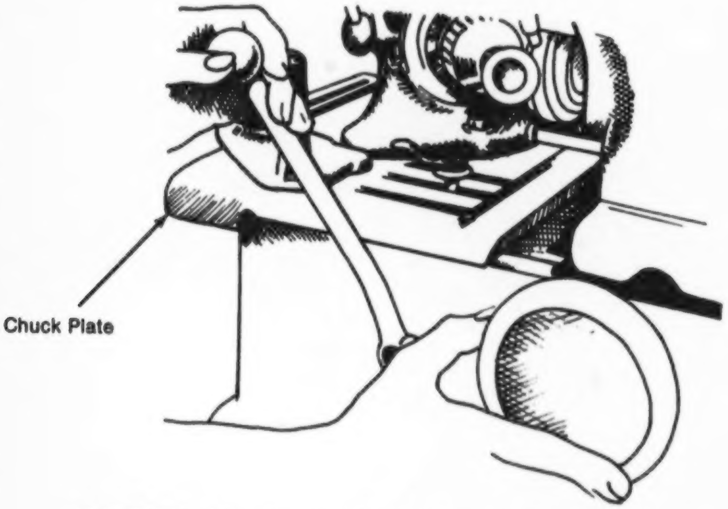
5) Press valve firmly back into aligner and release lever.

6) Tighten by hand to desired tension.

JOB SHEET #2

d. Grind valves. (Figure 9)

FIGURE 9



(CAUTION: Adjust stop chuck plate so grinding stone will not get into valve stem.)

1) Switch on motor.

2) Advance valve in front of grinding wheel until wheel just touches valve.

   (NOTE: Adjust coolant nozzle as required.)

3) Set micrometer on feed screw at zero.

4) Begin grinding at left side of wheel, moving valve slowly and steadily across wheel then back again.

5) Take light cuts by feeding the wheel up to the valve .001 or .002 at a time.

6) Remove just enough material to make a clean, smooth face.

7) When valve face is trued, advance to right until top edge of valve is flush with right edge of wheel.

   (CAUTION: Do not let valve leave the stone.)

8) Stop a second or two, then back grinding wheel away from valve.

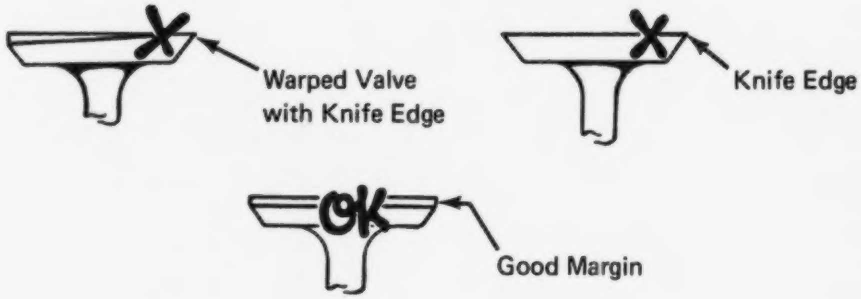
9) Repeat steps above for other valves.

   (NOTE: Keep valves in numbered rack to make sure you return them to the proper guides.)

JOB SHEET #2

10) Replace any valve that cannot be entirely refaced while keeping a good valve margin. (Figure 10)

FIGURE 10


X
Warped Valve with Knife Edge
X
Knife Edge
OK
Good Margin

(CAUTION: Avoid a knife edge around part or all of the valve head. See Figure 10.)

(NOTE: Inspect valve stem for nicks. Also check manufacturer's specifications about grinding valve stem tip; some recommend grinding the stem and others do not.)

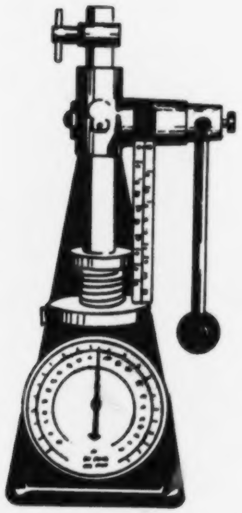
5. Inspect valve spring.
   a. Inspect for:
      1) Wear on the casting where springs rotate.
      2) Wear on the spring caps.
      3) Wear on ends of spring.
      4) Warped springs.

JOB SHEET #2

b. Test spring tension.

1) Mount valve spring on spring tester. (Figure 11)

FIGURE 11



2) Measure spring length by means of manufacturer's standards.

3) Compress valve spring.

(NOTE: If valve springs compress to dimensions shown in manufacturer's table at less than load indicated under "worn limits," valve spring should be discarded.)

Obtain instructor's initials here ____________.

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #3 — SERVICE VALVE GUIDES

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Appropriate service manual
4. Basic hand tool set
5. Electric hand drill
6. Rotary wire cleaning brush
7. Valve seat grinding kit
8. 0-1 inch micrometer
9. Small bore gauge
10. Bluing or lead pencil

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Service valve guides.
   a. Clean valve guides.
      1) Use correct size wire brush in an electric drill.

JOB SHEET #3

2) Run brush up and down the full length of guide. (Figure 1)

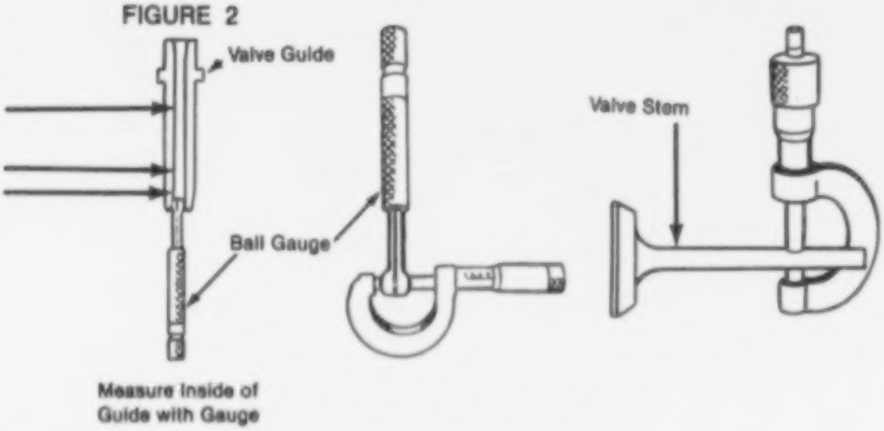
FIGURE 1

3) Apply a few drops of oil.

b. Inspect valve guides.

1) Measure at different points within the guide using ball gauges. (Figure 2)

FIGURE 2


Valve Guide
Valve Stem
Ball Gauge
Measure Inside of Guide with Gauge

2) Read measurement with micrometer.

3) Measure outside of valve stem. (Figure 2)

4) Compare (2) and (3) for clearance.

(NOTE: If guide to stem clearance is more than 50 percent above manufacturer's specifications, replace.)

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #3

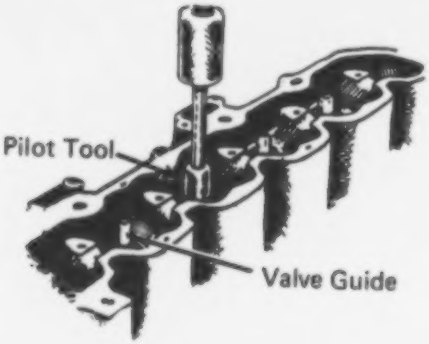
c. Replace valve guides.

1) Remove old valve guide.

(NOTE: Check with appropriate service manual for correct valve guide removal and installing tool.)

2) Install new guides as needed. (Figure 3)

FIGURE 3



(NOTE: Check service manual specifications for valve guide height.)

JOB SHEET #3

3) Precision-ream to specifications after installation, if required.

Obtain instructor's initials here ____________.

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #4 — GRIND VALVE SEATS

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Appropriate service manual
4. Cylinder head holding fixture
5. Basic hand tool set
6. Electric hand drill
7. Rotary wire cleaning brush
8. Valve seat grinding kit
9. 0-1 inch micrometer
10. Small bore gauge
11. Bluing or lead pencil

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clean valve seats. (Figure 1)

FIGURE 1

JOB SHEET #4

a. Use an electric hand drill with wire brush to remove all carbon.

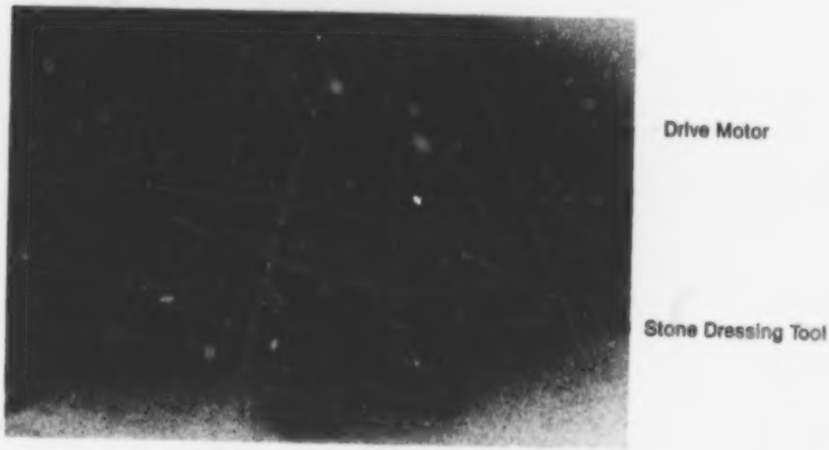
b. Apply kerosene to loosen carbon.

c. Check for pitted, burned, or worn seat.

2. Dress grinding wheel.

   a. Set dressing tool at desired angle. (Figure 2)

   FIGURE 2



   b. Put a drop of very light oil on dressing pilot.

   (CAUTION: Do not get oil on grinding wheel.)

   c. Screw grinding wheel on holder and place on pilot.

   d. Adjust until wheel just touches diamond.

   e. Insert driver and bring up to speed.

   f. Move diamond steadily across wheel, taking light cuts.

3. Select tapered pilot. (Figure 3)

   a. Select largest pilot which will fit snugly into valve guide.

   b. Place drop of oil on pilot, insert into guide, and twist gently to lock. (Figure 3)

      FIGURE 3

      (NOTE: There are also expandable pilots available.)

4. Select grinding wheel.

   a. Screw proper grinding wheel onto holder and place on pilot. (Figure 4)

      (NOTE: Refer to service manual for size and angle.)

      FIGURE 4

(CAUTION: Be sure seal is level or at 90° to grinding wheel.)

JOB SHEET #4

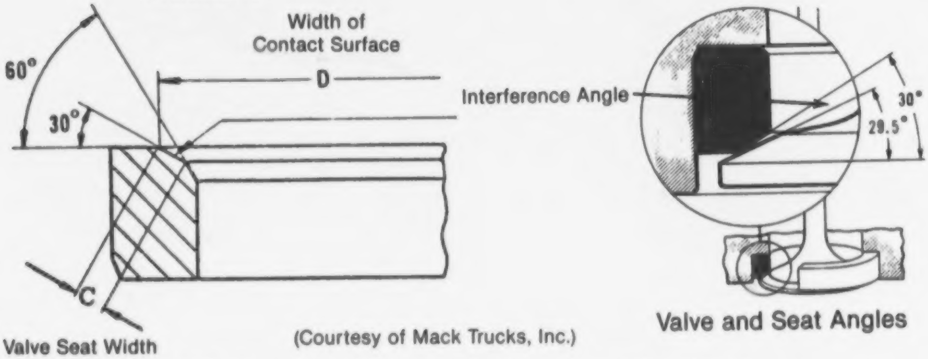
b. Place driver into grinding wheel holder, and operate driver until seat has been ground to the proper finish. (Figure 5)

FIGURE 5

c. Visually check seat for cracks and seat width.

d. Grind the valve seat so that little of the valve face is exposed to the combustion chamber. (Figure 6)

FIGURE 6


60°
30°
Width of Contact Surface
D
C
Valve Seat Width
Interference Angle
30°
29.5°

(Courtesy of Mack Trucks, Inc.)

Valve and Seat Angles

(NOTE: Narrow seat to manufacturer's specifications.)

e. Precautions:

1) Do not grind too long, only a few seconds.

2) Do not use too much pressure.

3) Keep work area clean.

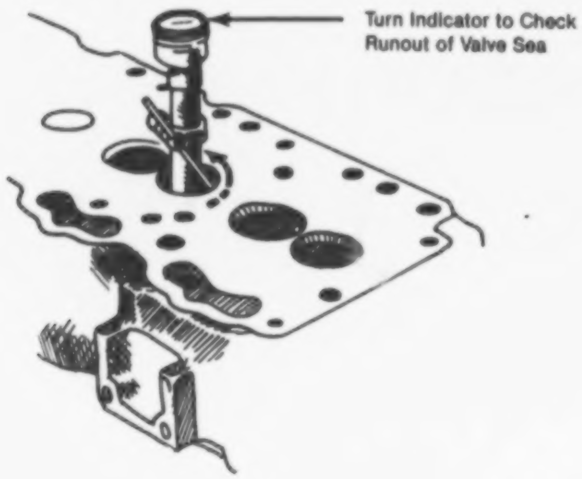
JOB SHEET #4

4) Check seat width and contact pattern with bluing or lead pencil marks.

5) Regrind uneven spots.

6) Check the runout (concentricity) of the valve seat with a dial indicator. (Figure 7)

FIGURE 7


Turn Indicator to Check
Runout of Valve Sea

(NOTE: Reading must be within specifications shown in the engine technical manual.)

7) Rotate the pilot 90° in the guide and take a second reading.

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #5 — REPLACE VALVE SEAT INSERTS

A. Tools and materials

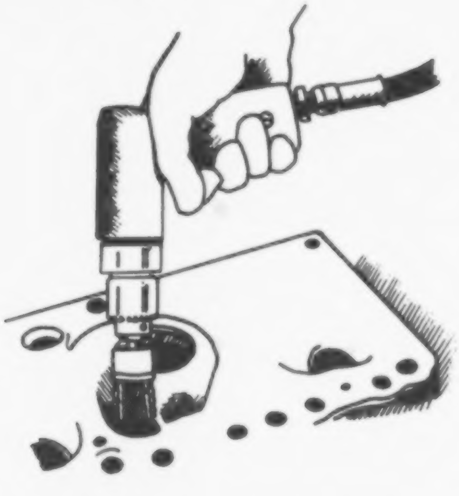
1. Safety glasses
2. Shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Valve seat insert puller
6. Rotary wire cleaning brush
7. Electric hand drill

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clean valve seats. (Figure 1)

FIGURE 1



   a. Use an electric drill with wire brush to remove all carbon.
   b. Apply kerosene to loosen carbon.
   c. Check for pitted, burned, or worn seat.

JOB SHEET #5

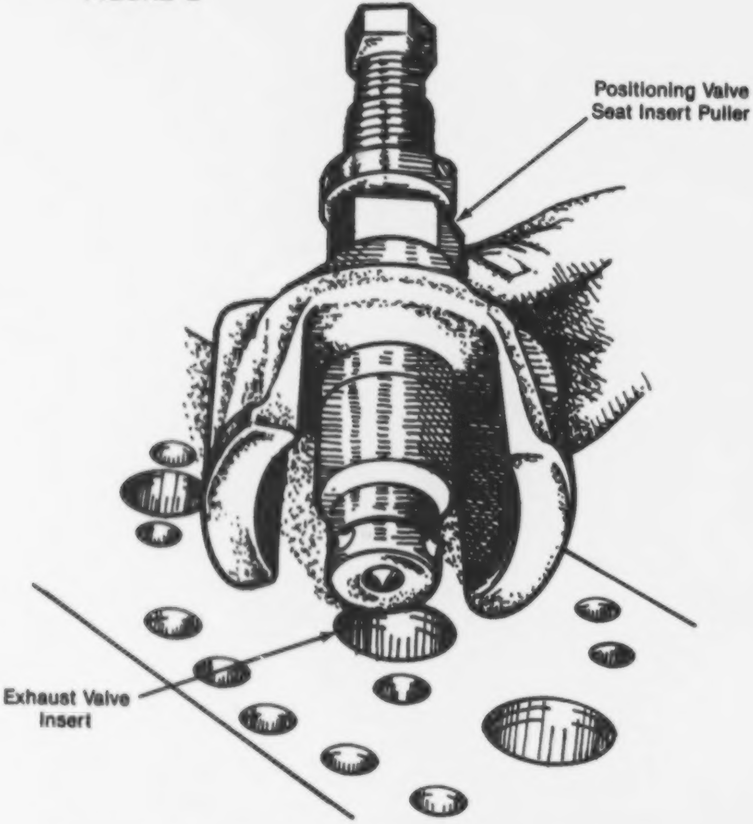
2. Check the valve seat insert for cracks or looseness by lightly tapping the cylinder head near the insert.

   (NOTE: If insert is loose enough to bounce, mark for replacement.)

3. Remove valve seat insert.

   a. Use a valve seat insert puller. (Figure 2)

FIGURE 2



(CAUTION: Do not use a prybar, punch, or chisel because the hardened materials shatter like glass and serious face or eye injury could result.)

   b. Upon removal, check the counterbore for burrs, cracks, or rough edges.

   Obtain instructor's initials here ____________ before proceeding to next step.

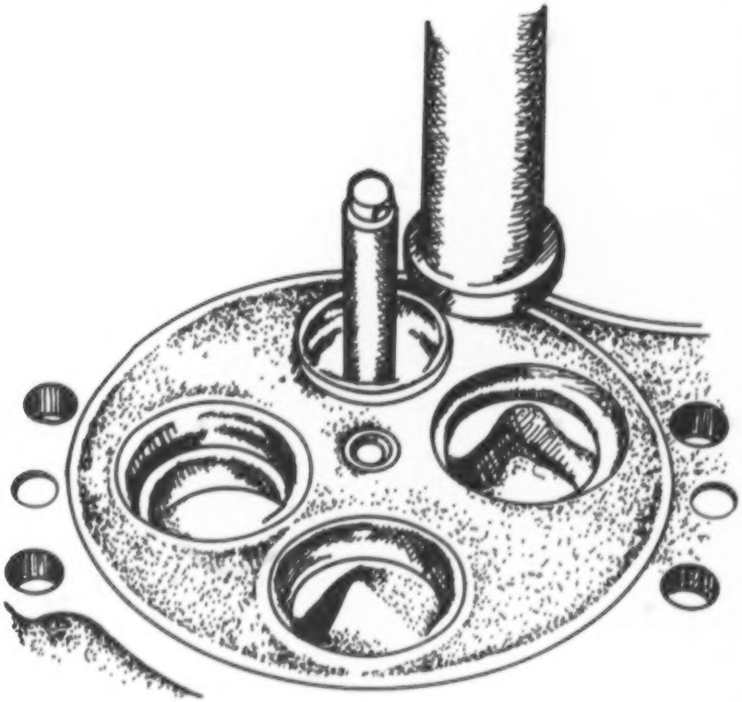
4. Install valve seat insert.

   a. Select correct size valve seat insert.

JOB SHEET #5

b. Drive or press the insert down tightly into the counterbore by using an insert driver. (Figure 3)

FIGURE 3



c. Check to see that insert is fully seated.

d. Check valve seat runout.

Obtain instructor's initials here ____________.

CYLINDER HEAD ASSEMBLY
UNIT II-B

JOB SHEET #6 — ASSEMBLE A CYLINDER HEAD

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Straightedge
6. Feeler gauges
7. Valve spring compressor
8. Vacuum tester

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Assemble cylinder head.

   a. Apply oil to valve stems and return to same ports from which they were removed.

   (NOTE: Commercial valve stem lubricants are available.)

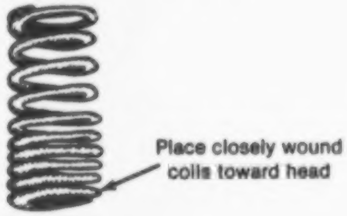
   b. Work the valves back and forth to make sure they slip through easily and seat properly.

   (NOTE: A properly seated valve will bounce when dropped on its seat.)

   c. Install valve seals if required and seat valve springs.

   (NOTE: Place closely wound end of spring to stationary side or toward head. See Figure 1.)

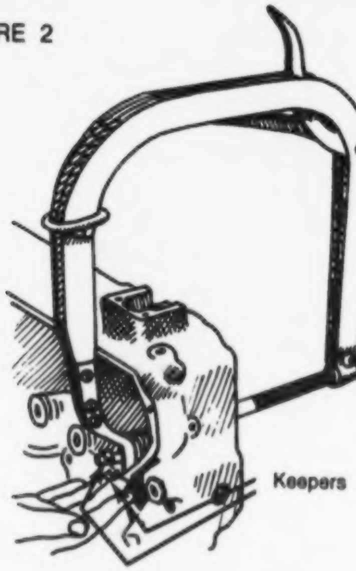
FIGURE 1



JOB SHEET #6

d. Install new valve keepers, if necessary, making sure they fit properly. (Figure 2)

FIGURE 2



e. Pop each spring and valve assembly three or four times by tapping on the end with a soft mallet.

Obtain instructor's initials here ____________ before proceeding to next step.

2. Check valve head height (protrusion).

   a. Place a straight edge across the cylinder head, and use a feeler gauge to measure distance between the valve head and straightedge.

   b. Zero gauge on cylinder head face next to the valve. Move the gauge over the valve and check for specified clearance.

3. Check valve stem height.

   (NOTE: This may affect installed valve spring height and tension. Shims may have to be added under the spring.)

4. Leakage test a valve.

   a. Put the vacuum cup over the valve.

   b. Open shutoff valve and operate the vacuum pump until the vacuum gauge indicates between 18 to 25 inch - hg (mercury).

JOB SHEET #6

c. Turn shutoff valve to closed position.

d. Check manufacturer's specifications for the amount of time allowed for vacuum leakage to be within specification.

Obtain instructor's initials here ____________.

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #1 — REMOVE, INSPECT, AND INSTALL A CYLINDER HEAD

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Followed all shop safety procedures.	______	______
3. Removed cylinder head correctly.	______	______
4. Cleaned cylinder head and block surfaces.	______	______
5. Checked fuse plug.	______	______
6. Checked cylinder head for warpage.	______	______
7. Checked cylinder head for leaks or cracks.	______	______
8. Installed cylinder head correctly.	______	______
9. Torqued cylinder head in sequence.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Cylinder head is removed correctly.	4	3	2	1
Cylinder head is in good condition.	4	3	2	1
Cylinder head is installed correctly.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #2 — DISASSEMBLE AND SERVICE A VALVE TRAIN

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Removed valve from cylinder correctly.	______	______
4. Cleaned valve correctly.	______	______
5. Inspected all valves.	______	______
6. Dressed grinding wheel.	______	______
7. Refaced valve properly.	______	______
8. Rechecked conditions of valve face.	______	______
9. Checked valve spring tension.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Valve is removed properly.	4	3	2	1
Valve is refaced properly.	4	3	2	1
Spring tension is correct.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #3 — SERVICE VALVE GUIDES

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Used shop safety precautions.	______	______
3.	Cleaned valve guides correctly.	______	______
4.	Used ball gauge to inspect guides.	______	______
5.	Removed valve guides correctly.	______	______
6.	Installed valve guides correctly.	______	______
7.	Checked in/put away tools and materials.	______	______
8.	Cleaned the work area.	______	______
9.	Used proper tools correctly.	______	______
10.	Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11.	Practiced safety rules throughout procedure.	______	______
12.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Valve guides are clean.				
	4	3	2	1
Valve guides are removed properly.				
	4	3	2	1
Valve guides are installed properly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

D-105-B

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #4 — GRIND VALVE SEATS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned valve seats.	______	______
4. Dressed grinding wheel.	______	______
5. Ground valve seat to proper angle.	______	______
6. Checked valve seat for runout.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Valve seat is properly ground.	4	3	2	1
Valve seat runout is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #5 — REPLACE VALVE SEAT INSERTS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned valve seat area.	______	______
4. Removed valve seat insert.	______	______
5. Checked counterbore.	______	______
6. Installed valve seat insert.	______	______
7. Checked valve seat runout.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Valve seat insert is removed properly.	4	3	2	1
Valve seat insert is installed properly.	4	3	2	1
Valve seat insert has proper runout.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER HEAD ASSEMBLY
UNIT II-B

PRACTICAL TEST
JOB SHEET #6 — ASSEMBLE A CYLINDER HEAD

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed valves into cylinder head correctly.	______	______
4. Checked valve head height.	______	______
5. Checked valve stem height.	______	______
6. Tested valve and seat for leakage.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Valves are installed properly.	4	3	2	1
Valve head height is correct.	4	3	2	1
Valve stem height is correct.	4	3	2	1
Valve and seat leakage test is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER HEAD ASSEMBLY
UNIT II-B

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms related to a cylinder head with the correct definitions.

_____a. To clean, inspect, lubricate, and/or adjust

_____b. Disk with a stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring

_____c. That part in the head upon which the valve face rests to close the port

_____d. Hole through which the stem of the valve passes

_____e. Helical spring used to close the valve

_____f. Hold the valve spring on the valve stem

_____g. Lever that transmits the action of the cam to the stem of the valves

_____h. Serves as a fulcrum for rocker arms

_____i. Shaft, rocker arm, and cam follower

_____j. Intermediate contact between camshaft and valve stem

_____k. High velocity swirling of air within the combustion chamber

_____l. Angle between the seat surface and the cylinder head surface, either 30 or 45 degrees

_____m. A twisting effort

_____n. Wrench used to draw nuts to a specified tension by measuring the twisting effort in foot-pounds

1. Cam follower
2. Foot-pound
3. Fuel injection nozzle
4. Fuel injector
5. Interference angle
6. Poppet valve
7. Rocker arm
8. Rocker arm assembly
9. Rocker arm shaft
10. Service
11. Sodium filled valves
12. Torque
13. Torque wrench
14. Turbulence
15. Valve bridge
16. Valve face angle
17. Valve guide

TEST

______o. Unit of measure of torque

______p. Meters and sprays fuel into the combustion chamber

______q. Injects fuel under high pressure

______r. Angle between the valve face and the valve stem

______s. A sealing device which prevents excess oil from entering the area between the stem and the valve guide

______t. Valves that have been hollowed and partially filled with metallic sodium to reduce valve-head temperature

______u. Permits a narrow leakfree valve seat when the engine is first started; as the valve gets hot, the valve head curls slightly and expands to a full seat contact.

______v. The distance between the edge of the valve and the edge of the face

______w. Permits two valves in the same cylinder to be opened at the same time

18. Valve margin
19. Valve seat
20. Valve seat angle
21. Valve spring
22. Valve spring retainers
23. Valve stem seal

2. Select the major parts usually found in a cylinder head assembly by placing an "X" next to the part.

______a. Rocker arm

______b. Wrist pin

______c. Exhaust valve

______d. Valve guides

______e. Main bearing

______f. Valve seats

______g. Fuel injector or nozzle

______h. Connecting rod

______i. Intake valve

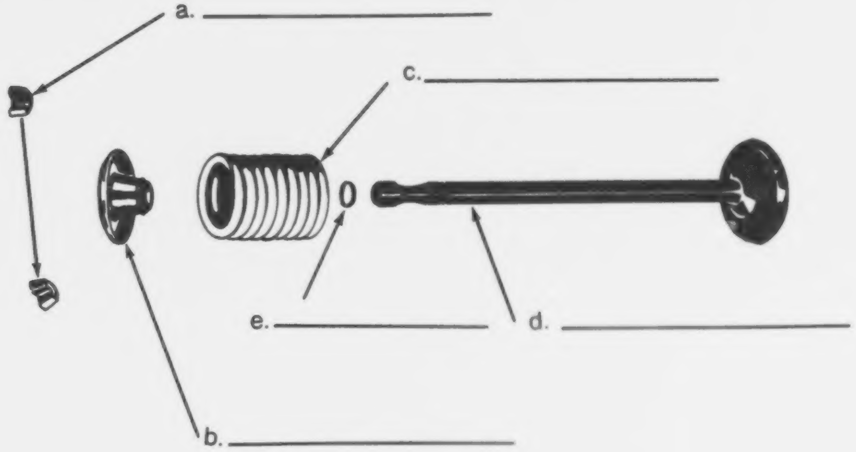
______j. Fuel injector tube

TEST

3. Identify three forms of cylinder head castings that may be found on a diesel engine.

a. ______________________ b. ______________________

4. Identify the primary parts in a valve assembly.



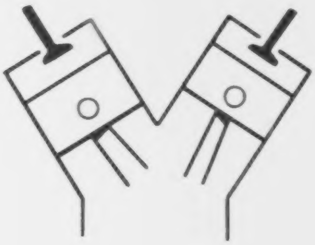
TEST

5. List two types of valve rotators.

a. ______________________________

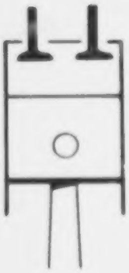
b. ______________________________

6. Identify the types of valve arrangement.



Both valves above angled cylinders

a. ______________________________



Both valves above cylinder

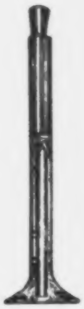
b. ______________________________

7. List two locations for turbulence chambers in the engine.

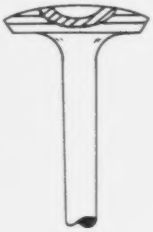
a. ______________________________

b. ______________________________

8. Identify the forms of engine valves.

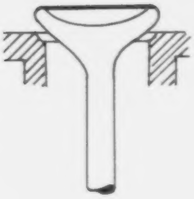


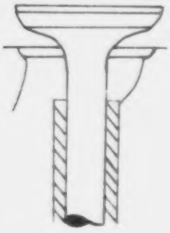
a. ______________________________



b. ______________________________

TEST





c. ______________________________ d. ______________________________

9. Name three factors determining cylinder head size.

   a. ____

   b. ____

   c. ____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Demonstrate the ability to:

    a. Remove, inspect, and install a cylinder head. (Job Sheet #1)

    b. Disassemble and service a valve train. (Job Sheet #2)

    c. Service valve guides. (Job Sheet #3)

    d. Grind valve seats. (Job Sheet #4)

    e. Replace valve seat inserts. (Job Sheet #5)

    f. Assemble a cylinder head. (Job Sheet #6)

CYLINDER HEAD ASSEMBLY
UNIT II-B

ANSWERS TO TEST

1.

a.	10	g.	7	m.	12	s.	23
b.	6	h.	9	n.	13	t.	11
c.	19	i.	8	o.	2	u.	5
d.	17	j.	1	p.	4	v.	18
e.	21	k.	14	q.	3	w.	15
f.	22	l.	20	r.	16		

2. a, c, d, f, g, i, j

3. a. Multiple
   b. One piece

4. a. Split collar retainer (valve keepers)
   b. Valve spring cup
   c. Valve spring
   d. Valve
   e. Valve stem seal

5. a. Release type
   b. Positive type

6. a. H-head
   b. I-head

7. a. Chamber in cylinder head
   b. Chamber in piston

8. a. Sodium-filled
   b. Standard
   c. Tulip
   d. Flat-top

9. Any three of the following:
   a. Cylinder block design
   b. Number of main bearings
   c. Expected thermal stress
   d. Cooling and sealing difficulties of the cylinder head
   e. The design of the intake and exhaust ports
   f. Number and size of cylinders

10. Performance skills evaluated to the satisfaction of the instructor

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the primary parts of a piston and connecting rod assembly and select the causes of high oil consumption and blow-by. The student should also be able to inspect and measure pistons and crankshaft for wear. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to piston and connecting rod assemblies with the correct definitions.
2. Identify primary parts of a piston and connecting rod assembly.
3. List functions of the piston.
4. Identify main parts of a piston.
5. Select functions of piston rings.
6. Name types of piston rings.
7. Identify common types of ring end gaps.
8. Select possible causes of high oil consumption and blow-by.
9. Name types of piston pins.

OBJECTIVE SHEET

10. Identify types of construction for the cap end of a connecting rod.

11. Complete a list of statements concerning the reasons for markings on the connecting rod, piston, and bearing cap.

12. Demonstrate the ability to:

    a. Remove piston and connecting rod assembly. (Job Sheet #1)

    b. Remove piston rings and piston from rod. (Job Sheet #2)

    c. Clean pistons. (Job Sheet #3)

    d. Inspect and measure pistons for wear. (Job Sheet #4)

    e. Inspect connecting rod. (Job Sheet #5)

    f. Assemble piston to rod and install rings. (Job Sheet #6)

    g. Install piston and connecting rod assembly into cylinder. (Job Sheet #7)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet and worksheet.

F. Discuss information sheet and worksheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Have students list different coatings on rings.
2. Have students make a price list of items necessary to perform job sheets using their own cars.
3. Have students make a list of the different types of piston pin designs and their uses.
4. Demonstrate removing and installing piston rings.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Engine Shop Manual.* Columbus, IN: Cummins Engine Company, 1974.

REFERENCES USED IN DEVELOPING THIS UNIT

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

C. *Detroit Diesel Service Manual.* Detroit, MI: General Motors, Inc., 1985.

D. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

E. Kates, Edgar J., and William E. Luck. *Diesel and High Compression Gas Engines.* 3rd ed. Chicago: American Technical Society, 1974.

F. *Mack Service Manual.* Allentown, PA: Mack Educational Communications, Inc., 1984.

G. Schulz, Erich. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. *Oil and Your Engine*
Caterpillar Inc.
Service Training, Building JJ
East Peoria, IL 61630

2. *Motor Magazine*
Motor Publications
555 West 57th Street
New York, NY 10019

B. Filmstrips

1. *Mack 6 Cylinder Engine Rebuild* — Part I
Educational Communications, Inc.
Dept. M
761 Fifth Avenue
King of Prussia, PA 19406

2. *Pistons, Rings, and Liners* (57 slides and cassette)
Caterpillar, Inc.
Literature Order Section
P.O. Box 5319
Morton, IL 61550

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

INFORMATION SHEET

I. **Terms and definitions**

A. Blow-by — Combustion gases escaping to the crankcase

B. Cam ground piston — A piston that is ground slightly oval but becomes round when heated

C. Connecting rod — A rod which joins the piston with the crankshaft

D. Incandescent — Glowing or burning

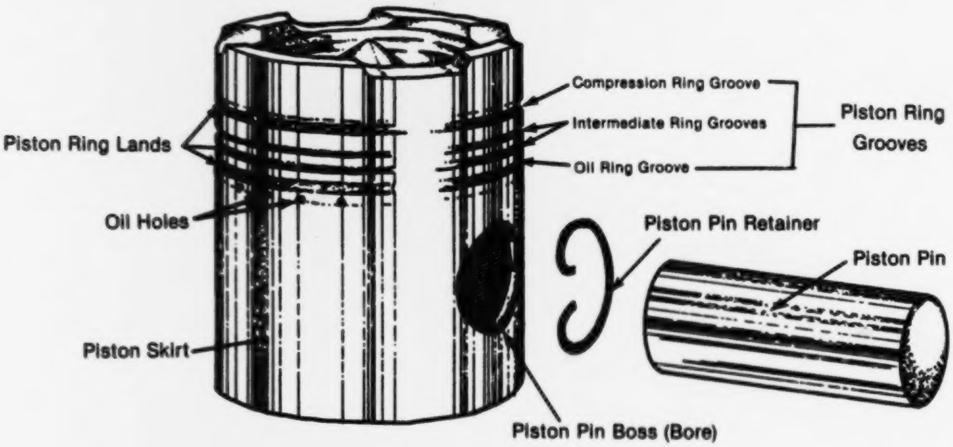
E. Lugging — Overloading, causing unusual stress

F. Piston oil holes — Holes drilled through the piston wall which allow the oil to escape after the oil-control rings wipe it off the cylinder wall

G. Piston pin — Pin that ties the piston and rod together

H. Piston pin boss — Hole in piston which supports piston pin

I. Piston pin retainer — A fastening device located in the piston pin boss which holds the piston pin in place


Compression Ring Groove
Intermediate Ring Grooves
Oil Ring Groove
Piston Ring Grooves
Piston Ring Lands
Oil Holes
Piston Pin Retainer
Piston Pin
Piston Skirt
Piston Pin Boss (Bore)

J. Piston rings — Split rings which are expanded and placed into the grooves of the piston; the rings seal the space between the cylinder wall and the piston

INFORMATION SHEET

K. Piston ring end gap — The amount of clearance between the split ends of the piston rings

L. Piston ring groove — A groove machined in the piston which holds the piston ring

M. Piston ring land — Area between ring grooves

N. Piston skirt — Outside part of piston below ring grooves

II. **Primary parts of a piston and connecting rod assembly** (Transparency 1)

A. Piston

B. Piston rings

C. Piston pin

D. Piston pin bushing

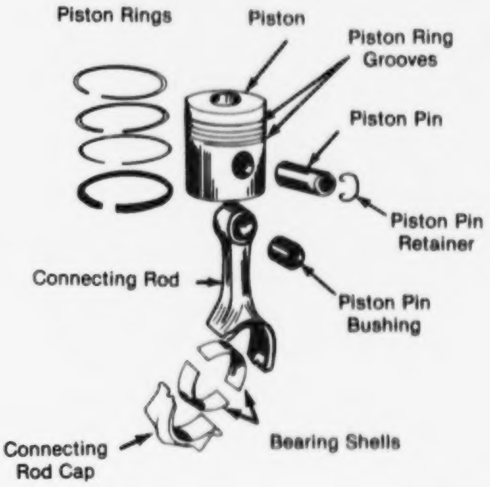
E. Connecting rod

F. Connecting rod cap

G. Bearing shells

H. Piston ring grooves

I. Piston pin retainer


Piston Rings
Piston
Piston Ring Grooves
Piston Pin
Piston Pin Retainer
Connecting Rod
Piston Pin Bushing
Connecting Rod Cap
Bearing Shells

III. **Functions of a piston**

A. Receives the force of combustion

B. Transmits this force to the crankshaft

C. Carries the piston rings which seal and wipe the cylinder

IV. **Main parts of a piston** (Transparency 1)

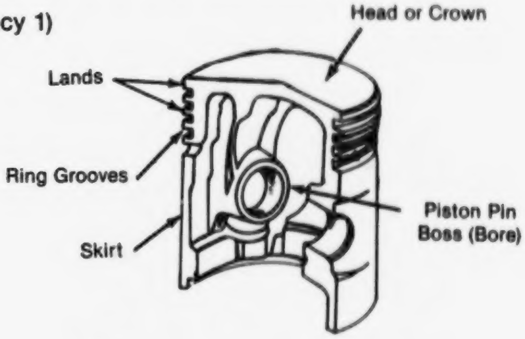
A. Head or crown

B. Skirt

C. Ring grooves

D. Lands

E. Piston pin boss


Head or Crown
Lands
Ring Grooves
Piston Pin Boss (Bore)
Skirt

INFORMATION SHEET

V. **Functions of piston rings**

   A. Forms a gas tight seal between the piston and cylinder wall

   B. Helps cool the piston by transferring heat

   C. Controls lubrication between piston and cylinder wall

VI. **Types of piston rings** (Transparencies 2 and 3)

   A. Compression

      1. First compression

         a. Plain

         b. Taper face

         c. Inside bevel

         d. Keystone

         e. ½ keystone

         f. Multipiece

      2. Second compression

         a. Counterbore

         b. Scraper

         c. Taper face twist

         d. Grooved face

   B. Oil control

      1. Ventilated

      2. Multipiece

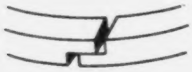
      3. Spring loaded

      4. Abutment

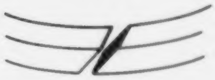
INFORMATION SHEET

VII. Common types of ring end gaps

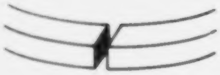
A. Step



B. Angle



C. Butt



VIII. Causes of high oil consumption and blow-by (Transparency 4)

A. Piston rings installed wrong

B. Stuck oil ring

C. Plugged oil ring

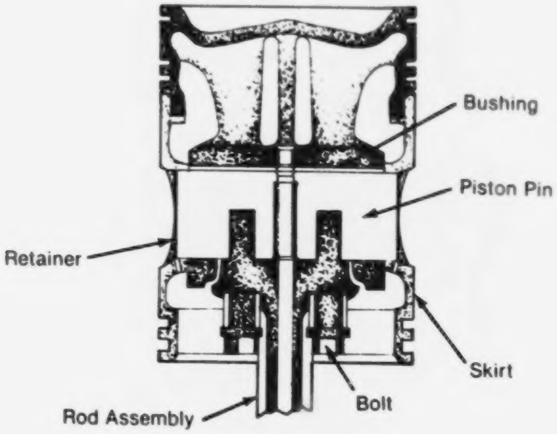
D. Top ring broken or top groove worn

E. Overall wear in piston, rings, and cylinder

F. Physical damage to pistons

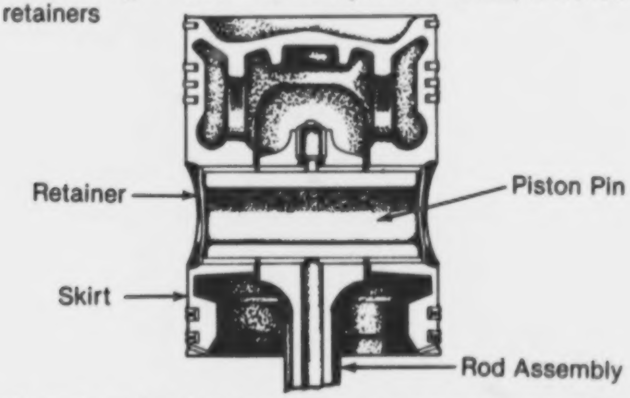
IX. Types of piston pins

A. Semi-floating — Moves in piston, fastened to rod (either pressed into rod or bolted to rod)


Bushing
Piston Pin
Retainer
Skirt
Bolt
Rod Assembly

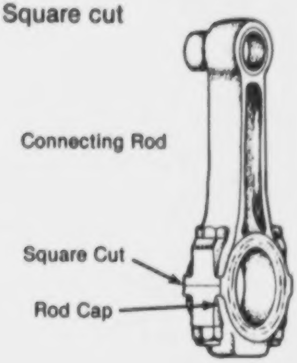
INFORMATION SHEET

B. Full floating — Moves in both piston and rod, fastened by spring clips or retainers

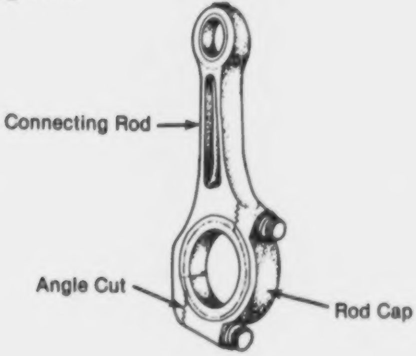

Retainer
Piston Pin
Skirt
Rod Assembly

X. **Types of construction for the cap end of a connecting rod** (Transparency 5)

A. Square cut

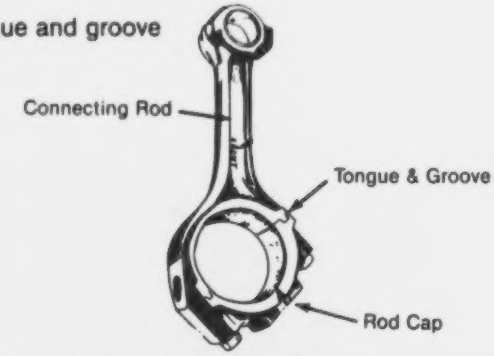

Connecting Rod
Square Cut
Rod Cap

B. Angle cut


Connecting Rod
Angle Cut
Rod Cap

INFORMATION SHEET

C. Tongue and groove


Connecting Rod
Tongue & Groove
Rod Cap

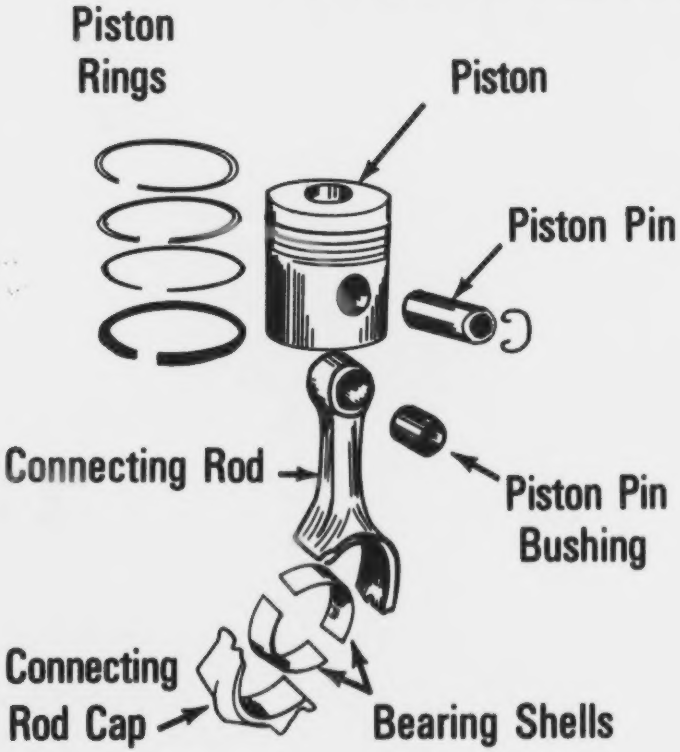
XI. **Reasons for markings** (Transparency 5)

A. On the piston — To install in same cylinder and on same side from which removed

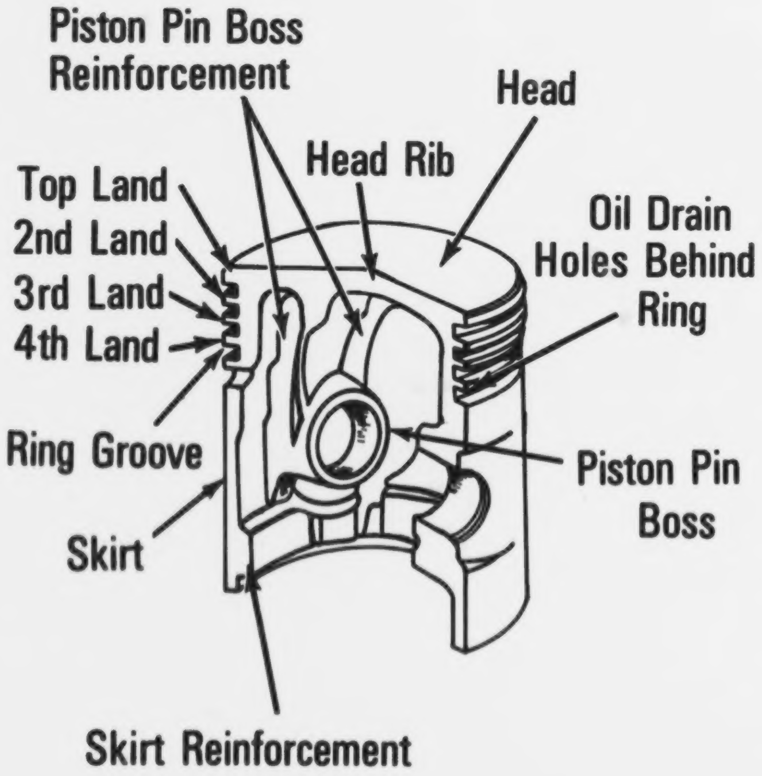
B. On the connecting rod — To install in same cylinder and on same side from which removed

C. On the bearing cap — To install on same rod and on same side from which removed

Piston and Connecting Rod Assembly


Piston Rings
Piston
Piston Pin
Connecting Rod
Piston Pin Bushing
Connecting Rod Cap
Bearing Shells

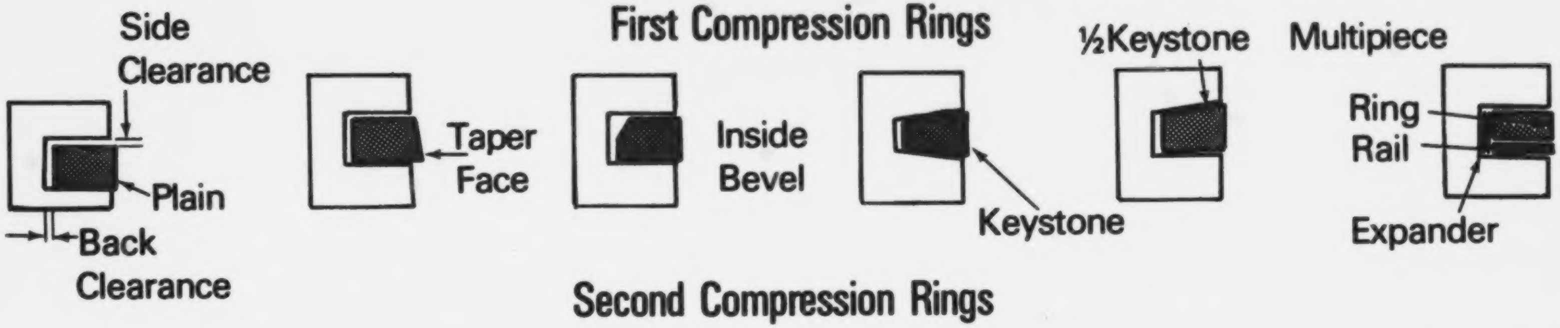
Complete Piston and Connecting Rod Assembly


Piston Pin Boss Reinforcement
Head
Head Rib
Top Land
2nd Land
3rd Land
4th Land
Oil Drain Holes Behind Ring
Ring Groove
Piston Pin Boss
Skirt
Skirt Reinforcement

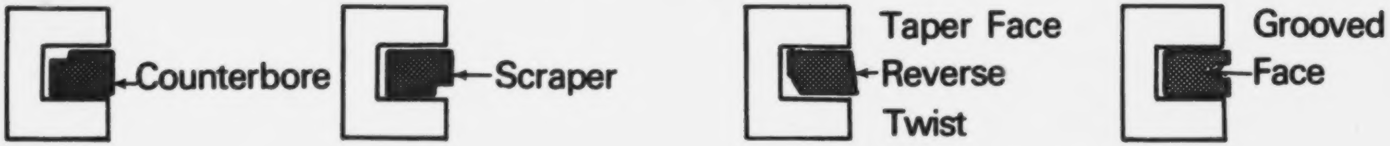
Piston

Piston Ring Design

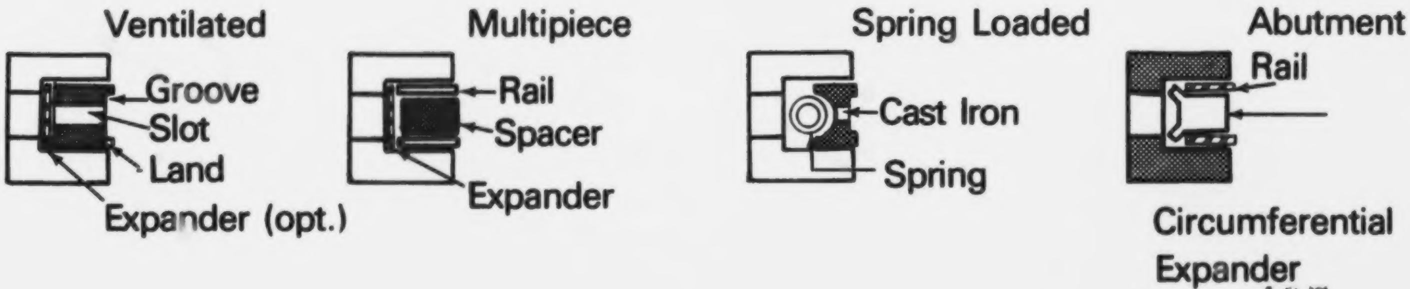
First Compression Rings


Side Clearance
Plain
Back Clearance
Taper Face
Inside Bevel
Keystone
½Keystone
Multipiece
Ring
Rail
Expander

Second Compression Rings


Counterbore
Scraper
Taper Face
Reverse
Twist
Grooved
Face

Oil Control Rings


Ventilated
Groove
Slot
Land
Expander (opt.)
Multipiece
Rail
Spacer
Expander
Spring Loaded
Cast Iron
Spring
Abutment
Rail
Circumferential
Expander

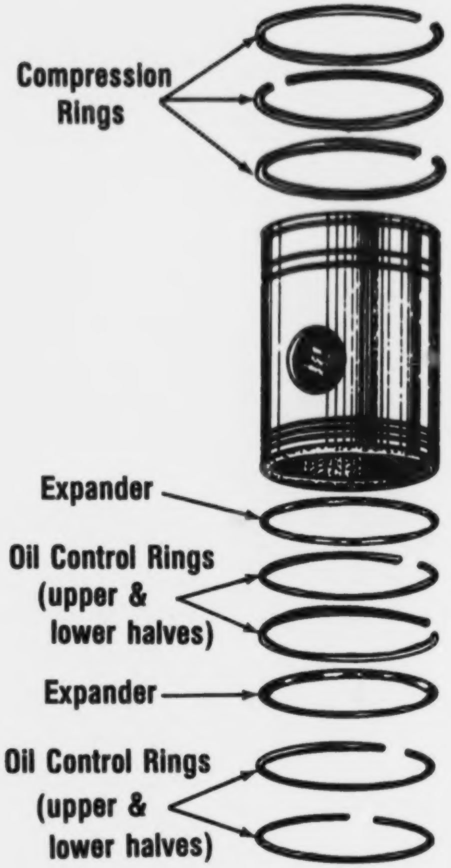
497

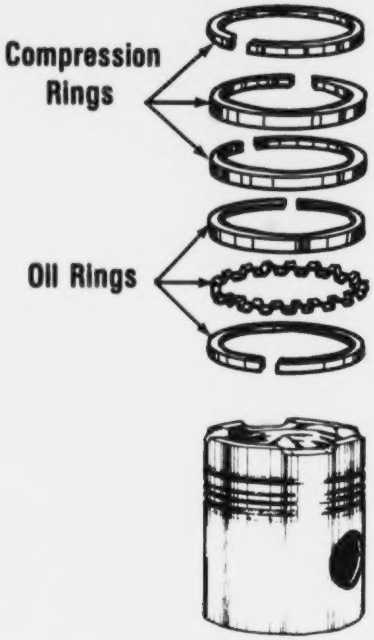
TM 2

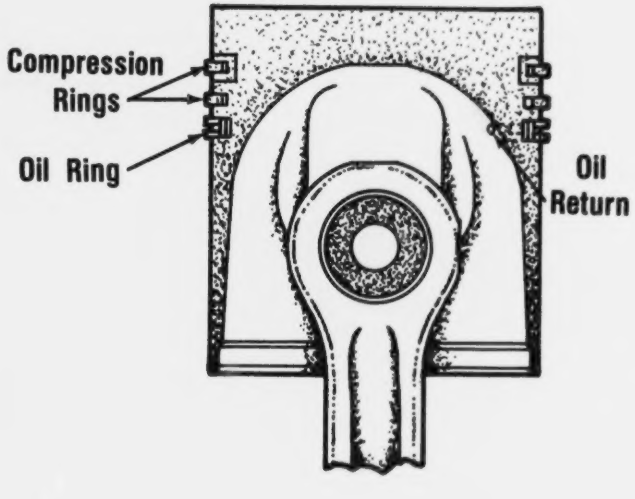
496

D-131-B

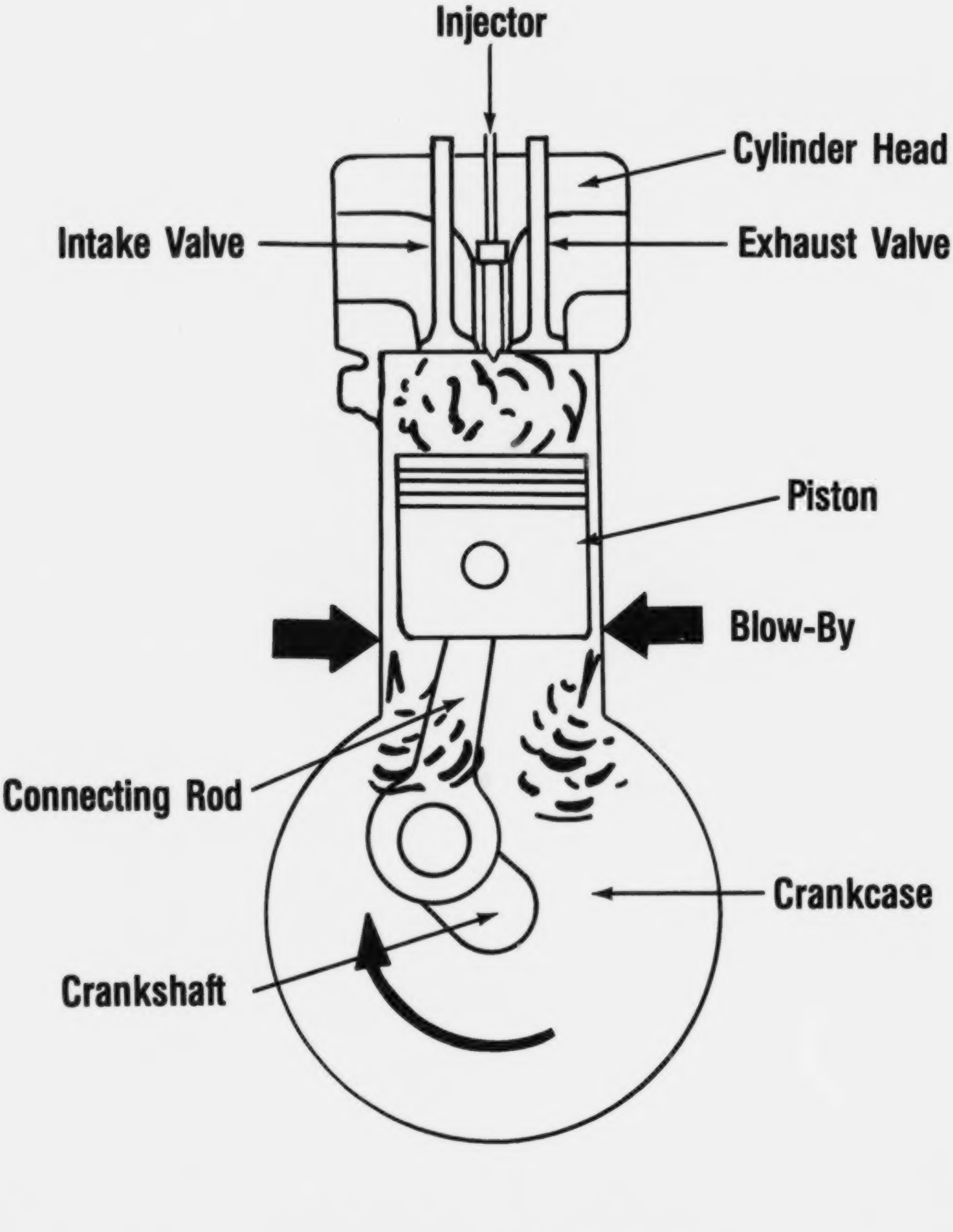
Piston Ring Arrangement


Compression Rings
Expander
Oil Control Rings (upper & lower halves)
Expander
Oil Control Rings (upper & lower halves)


Compression Rings
Oil Rings

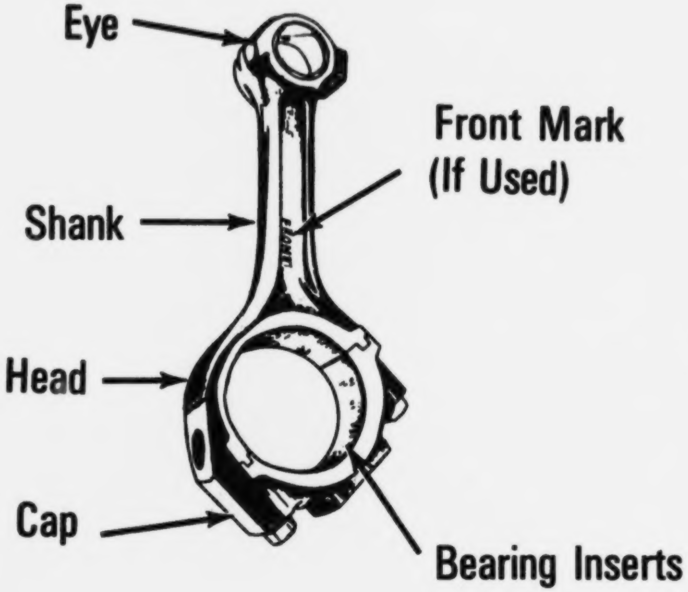

Compression Rings
Oil Ring
Oil Return

Blow-By

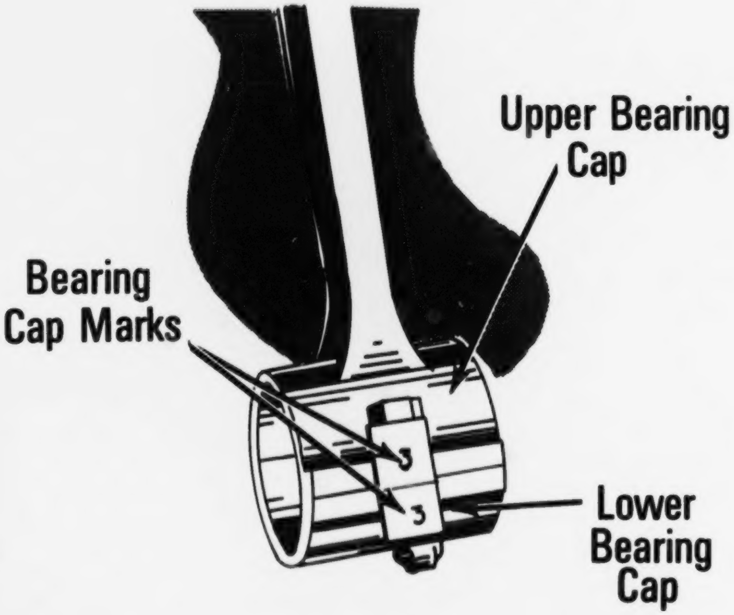

Injector
Cylinder Head
Intake Valve
Exhaust Valve
Piston
Blow-By
Connecting Rod
Crankcase
Crankshaft

Blow-by of Gases in Cylinder

Connecting Rod Markings


Eye
Front Mark (If Used)
Shank
Head
Cap
Bearing Inserts

Connecting Rod Angle Cut


Upper Bearing Cap
Bearing Cap Marks
3
3
Lower Bearing Cap

Connecting Rod Square Cut

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #1 — REMOVE PISTON AND CONNECTING ROD ASSEMBLY

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Drop light
6. Bench vise
7. Chemical cleaning solution
8. Solvent to remove oil film
9. Water spray supply
10. Compressed air supply
11. Plastic guide pins
12. "T-handle" pusher
13. Tags
14. Storage container

B. Procedure

(CAUTION: Follow all shop safety procedures.)

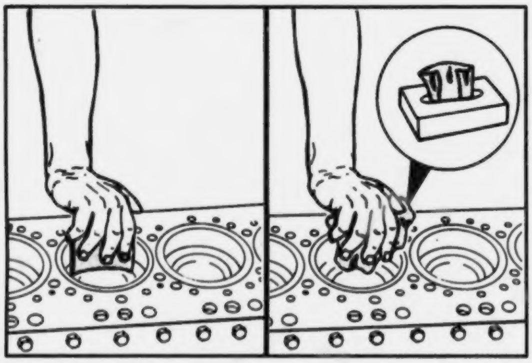
1. Remove cylinder head assembly and secure liner as necessary.

JOB SHEET #1

2. Clean the carbon ridge from top of cylinder liner by using a 240 grit emery cloth then wiping with a lint-free cloth.

   (NOTE: Soak the emery cloth in a cleaning solvent to prevent the cloth from becoming saturated with carbon deposit material.)

   FIGURE 1

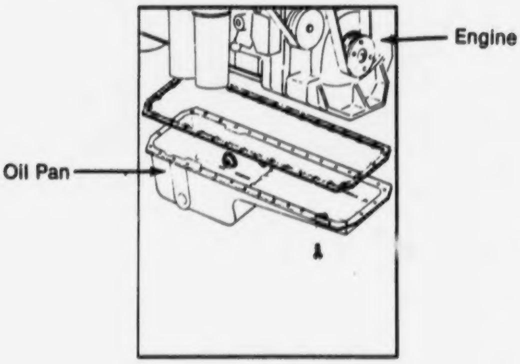


(Illustrations for Job Sheet #1 provided courtesy of Cummins Engine Company, Inc.)

(CAUTION: Do not damage the liner finish.)

3. Remove oil pan. (Figure 2)

   FIGURE 2



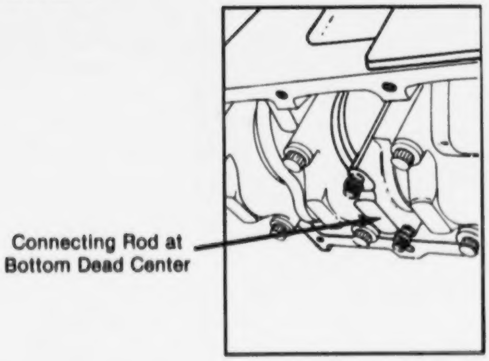
(NOTE: Store the pan bolts in a container.)

JOB SHEET #1

4. Rotate the crankshaft until two pistons are at bottom dead center. (Figure 3)

   (NOTE: Four-cycle engines have two pistons at bottom dead center at the same time; two-cycle engines have only one piston at bottom dead center at a time.)

   FIGURE 3



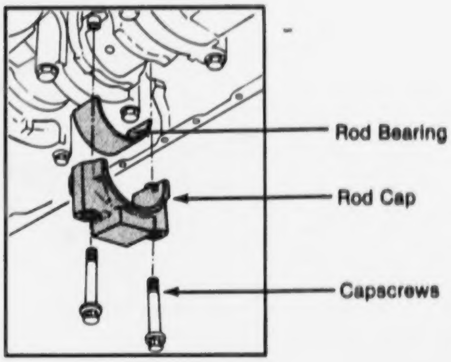
5. Check connecting rod and rod cap for numbers or marks before removing.

   (NOTE: The numbers or marks help ensure the piston is returned to its original cylinder.)

   Obtain instructor's initials here ____________ before proceeding to next step.

6. Remove the connecting rod capscrews, the rod cap, and lower rod bearing. (Figure 4)

   FIGURE 4



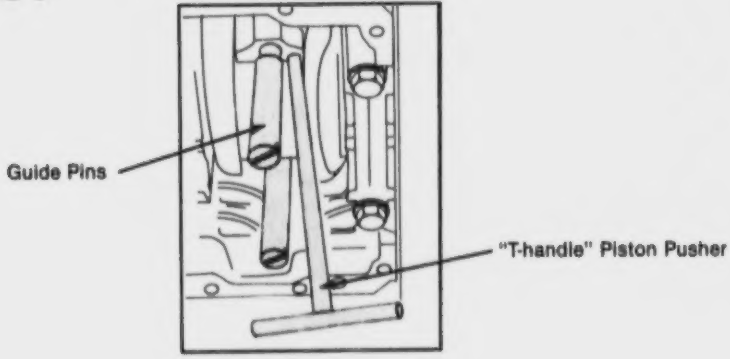
(NOTE: On some engines nuts are removed rather than capscrews.)

JOB SHEET #1

7. Place the connecting rod capscrews, rod cap, and rod bearing on a clean work bench until the piston is removed.

8. Install connecting rod guide pins. (Figure 5)

FIGURE 5


Guide Pins
"T-handle" Piston Pusher

(NOTE: If the connecting rod has nuts instead of capscrews, put a piece of hose around the bolts in the rod to protect the journals.)

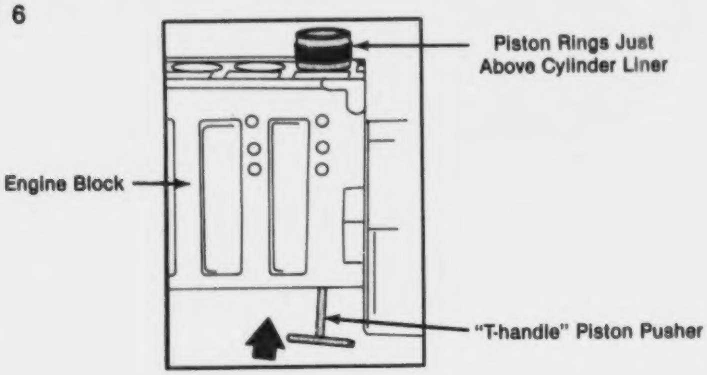
9. Use a "T-handle" piston pusher to push the rod away from the crankshaft. (Figure 5)

(NOTE: If you don't have a special tool to push on the rod, use a small piece of wood.)

10. Push the rod up until the piston rings are outside the top of the cylinder liner. (Figure 6)

(CAUTION: Do not damage the cylinder liner while pushing piston out of cylinder.)

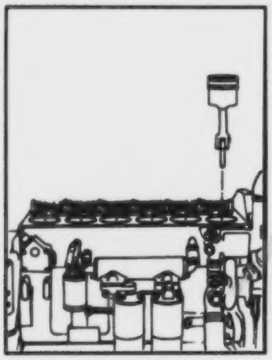
FIGURE 6


Piston Rings Just Above Cylinder Liner
Engine Block
"T-handle" Piston Pusher

JOB SHEET #1

11. Remove the piston and rod assembly. (Figure 7)

FIGURE 7

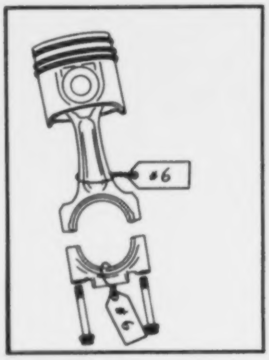


(CAUTION: The piston and connecting rod assemblies must be reinstalled into their original cylinder numbers.)

Obtain instructor's initials here ____________ before proceeding to next step.

12. Tag each piston and rod assembly with the original cylinder number to assure proper reinstallation. (Figure 8)

FIGURE 8



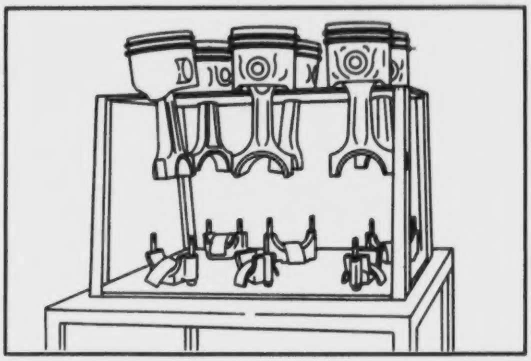
13. Replace cap on rod after removal.

14. Repeat above steps for remaining pistons.

JOB SHEET #1

15. Place the rod and piston assemblies in a container to protect them from damage. (Figure 9)

FIGURE 9



Obtain instructor's initials here ____________ .

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #2 — REMOVE PISTON RINGS AND PISTON FROM ROD

A. Tools and materials

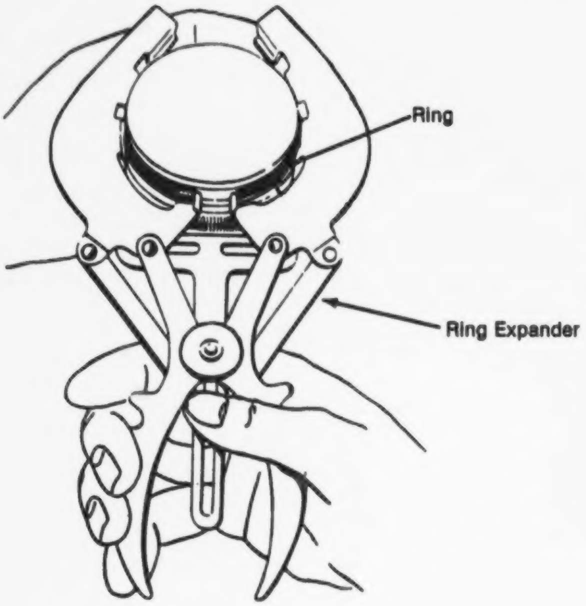
1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Snap ring pliers
6. Ring expander

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Use a ring expander and remove all rings from piston. (Figure 1)

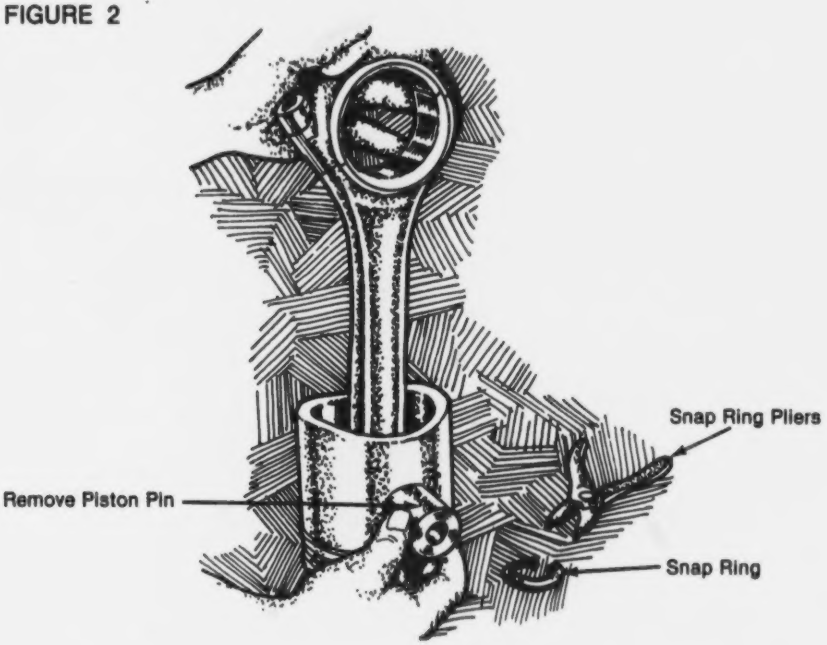
FIGURE 1



JOB SHEET #2

2. Remove retainer ring (snap ring) with snap ring pliers, and remove piston pin from the piston and connecting rod. (Figure 2)

FIGURE 2


Snap Ring Pliers
Remove Piston Pin
Snap Ring

(NOTE: Some semi-floating piston pins will require pressing the pin out of the piston or the rod.)

Obtain instructor's initials here ____________.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #3 — CLEAN PISTONS

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Solvent to remove oil film
6. Chemical cleaning solution
7. Glass bead machine (if used)

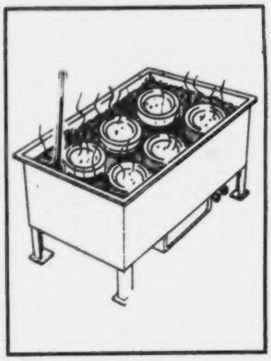
B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: To clean pistons, use one of the following methods.)

1. Use a chemical solution to soak pistons.
   a. Use a solvent to remove oil film from pistons.
   b. Mix the cleaner solution and heat as recommended.
   c. Soak the pistons in the cleaning solution for specified time. (Figure 1)

FIGURE 1



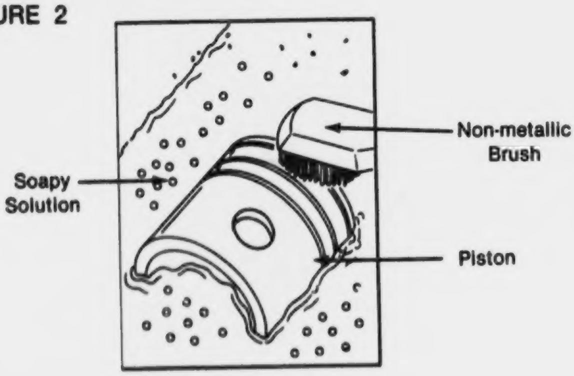
(Illustrations for Job Sheet #3 provided courtesy of Cummins Engine Company, Inc.)

(CAUTION: Make sure the cleaning solvent is approved for aluminum.)

JOB SHEET #3

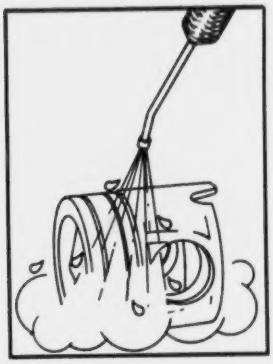
d. Use a hot, soapy solution and non-metallic brush to remove carbon deposits. (Figure 2)

FIGURE 2


Non-metallic Brush
Soapy Solution
Piston

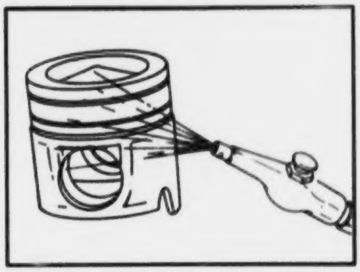
e. Steam clean the piston. (Figure 3)

FIGURE 3



f. Dry with compressed air. (Figure 4)

FIGURE 4



Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #3

B. Use glass beads to clean pistons.

(CAUTION: Check with the appropriate service manual for your piston; some manufacturers do not recommend glass beading.)

1. Wash pistons in solvent to remove grease and oil. (Figure 2)

   (CAUTION: Use a stiff brush, not a wire brush.)

2. Dry the pistons using compressed air. (Figure 4)
3. Clean the pistons in the glass bead cleaning machine using the proper size beads and correct pressure.
4. Keep the blast moving.

   (CAUTION: Do not hold bead blast on one area too long or metal may become eroded.)

5. Hold the nozzle away from the surface; distance will vary depending on recommended pressure.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #4 — INSPECT AND MEASURE PISTONS FOR WEAR

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Feeler gauges
6. Outside micrometers

B. Procedure

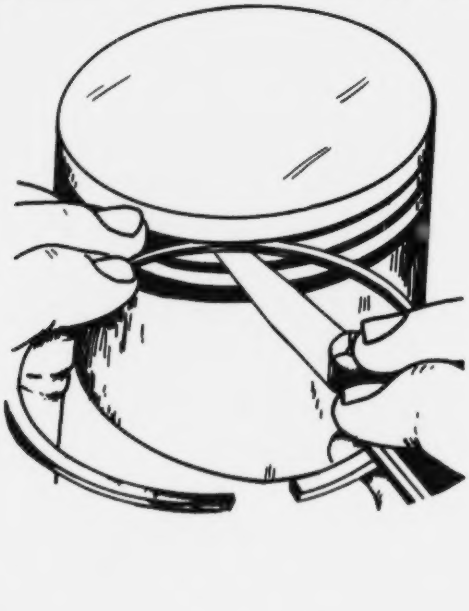
(CAUTION: Follow all shop safety procedures.)

1. Inspect pistons.
    a. Examine for score marks, damaged ring grooves, or signs of overheating.
    b. Inspect piston for cracks in head and skirt area and for bent or broken lands.

    (NOTE: Replace if damaged.)

2. Measure ring grooves for wear with feeler gauge. (Figure 1)

FIGURE 1



JOB SHEET #4

a. Install a new ring in groove.

b. Insert feeler gauge between upper surface of new ring and the land to check clearance. (Figure 1)

3. Measure ring grooves with wear gauge.

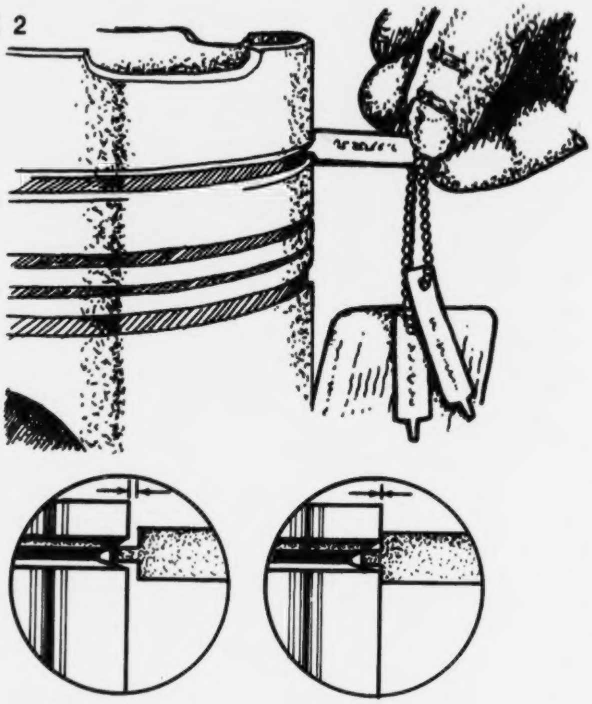
a. Make sure ring grooves are clean.

b. Place wear gauge in grooves.

c. Check to see if wide part of gauge touches piston. (Figure 2)

(NOTE: If wide part of gauge touches piston, the groove is worn too much and piston will have to be replaced.)

FIGURE 2



Satisfactory (Wide part does not touch.)

Unsatisfactory (Wide part touches. Groove is worn.)

d. Check all ring grooves at several points.

(NOTE: Follow engine manufacturer's recommendation for wear limits.)

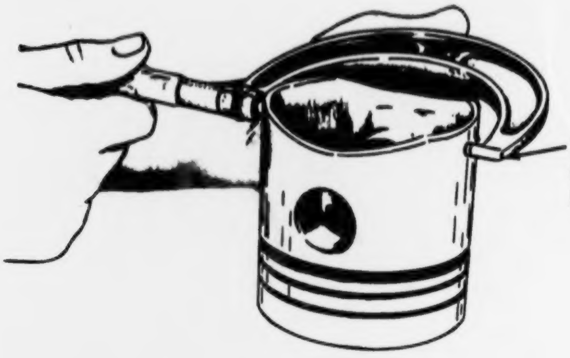
Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #4

4. Measure piston for wear.

   a. Using outside micrometers, measure the diameter of the piston skirt across the thrust faces (at right angles to the piston pin bore). (Figure 3)

      FIGURE 3



Place outside micrometer at right angle (90°) to piston pin bore

   b. Take a reading at both top and bottom of skirt.

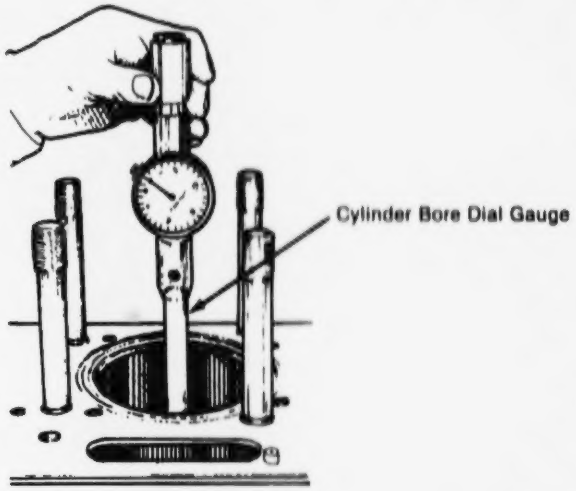
   c. Compare these measurements with the new dimensions given in the engine technical manual. The difference in measurements indicates the amount of piston wear.

JOB SHEET #4

5. Measure piston to cylinder clearance.

   a. Measure the cylinder diameter at right angles to the crankshaft in the lower or least-worn area of the cylinder, using a cylinder dial gauge, an inside micrometer, or a telescoping gauge with outside micrometer. (Figure 4)

FIGURE 4



   b. Measure the diameter of the piston across the thrust faces with an outside micrometer. (Figure 3)

   c. Compare the measurements. The difference between these two measurements is the piston clearance. Replace pistons if the clearance exceeds the manufacturer's specifications.

Obtain instructor's initials here _____________.

ENGINE MODEL NO. ______________

SERIAL NO. ______________

WORKSHEET #1 — INSPECTION WORKSHEET
PISTON AND CONNECTING ROD ASSEMBLY

PISTONS		1	2	3	4	5	6	SPECIFICATIONS	MAX PERMISSIBLE CLEARANCE
Head Condition									
Skirt Condition									
Ring Groove	Top								
	Middle								
	Bottom								
Piston Skirt Diameter	Top								
	Bottom								
Cylinder Diameter	Top								
	Bottom								
Piston Clearance									

CONNECTING ROD								
Rod Condition								
Rod & Rod Cap Radius								
Small Bore Diameter								
Large Bore Diameter								

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #5 — INSPECT CONNECTING ROD

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Cylinder bore gauge
6. Telescoping gauges
7. Set of outside micrometers

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Visually inspect connecting rod.
    a. Clean connecting rod with fuel oil, and dry with compressed air.
    b. Check the rod for twisting or bending.
    c. Check diameter and threads of rod bolts or capscrew.

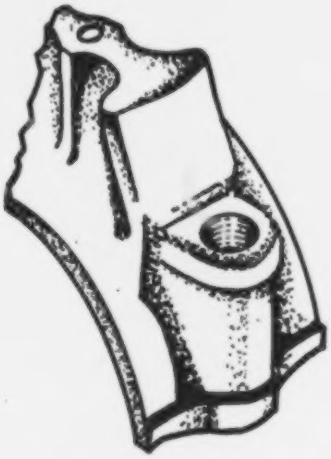
       (NOTE: Discard if any are damaged.)
    d. Check the bolt holes of rod and rod cap.

       (NOTE: Replace if not within specification.)

JOB SHEET #5

e. Check the radius on the rod and rod cap. (Figure 1)

FIGURE 1



2. Measure the small bore of rod.

   a. Place telescoping gauge into the bore.

   b. Remove telescoping gauge, and use the outside micrometer to accurately measure the telescoping gauge size.

   c. Check service manual to see if measurements are within manufacturer's specification.

3. Measure the large bore of rod.

   a. Assemble rod and rod cap without bearings, and tighten bolts lightly.

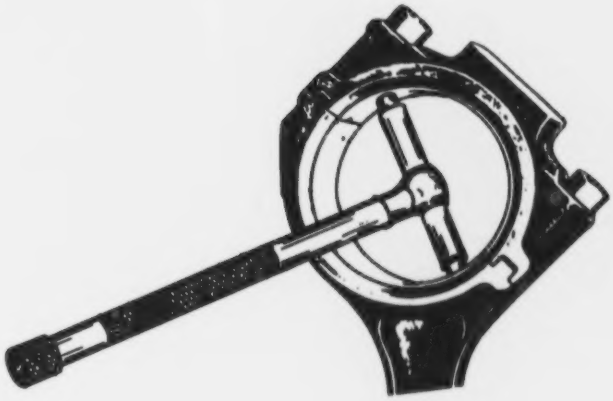
      (NOTE: Tap cap lightly with soft hammer to help align rod and cap.)

   b. Torque bolts or nuts to manufacturer's specifications.

   c. Place an inside micrometer or cylinder bore gauge into the rod bore and measure. (Figure 2)

JOB SHEET #5

FIGURE 2



d. Check service manual to see if measurements are within manufacturer's specification.

e. Replace the connecting rod if it does not meet specification.

Obtain instructor's initials here ____________.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #6 — ASSEMBLE PISTON TO ROD AND INSTALL RINGS

A. Tools and materials

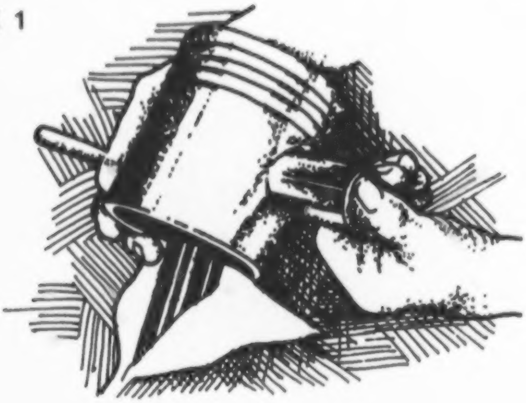
1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Snap ring pliers
6. Ring expander
7. Vise

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Install piston onto connecting rod.
   a. Place a rag or other protector over jaws of vise, and clamp the rod securely.
   b. Install the piston on the rod by inserting the piston pin through the rod and piston. (Figure 1)

FIGURE 1

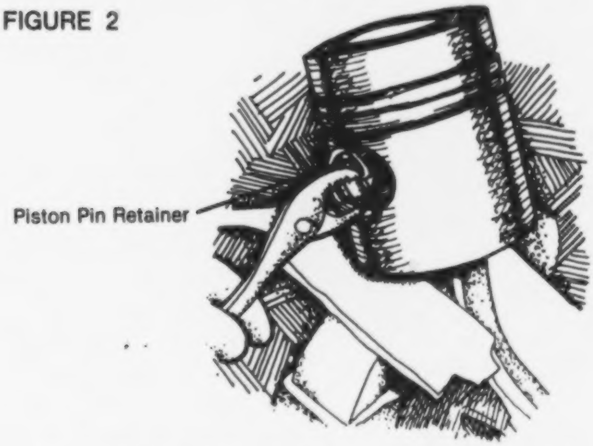


(NOTE: Some manufacturers recommend putting oil on piston pin before installing; check appropriate service manual before installing piston pin.)

JOB SHEET #6

2. Install piston pin retainers. (Figure 2)

FIGURE 2


Piston Pin Retainer

Obtain instructor's initials here ____________ before proceeding to next step.

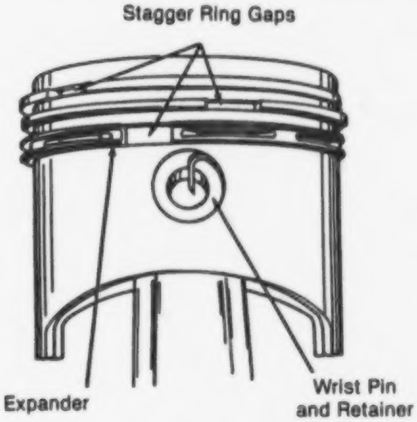
3. Install piston rings onto piston.

(NOTE: Refer to appropriate service manual or ring manufacturer for directions on installing different ring types.)

a. Using a ring expander, install piston rings onto piston.

b. Stagger the ring ends according to manufacturer's recommendations. (Figure 3)

FIGURE 3


Stagger Ring Gaps
Expander
Wrist Pin and Retainer

(CAUTION: Do not twist, expand, or stretch rings too much.)

Obtain instructor's initials here ____________.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

JOB SHEET #7 — INSTALL PISTON AND CONNECTING ROD ASSEMBLY INTO CYLINDER

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Ring compressor (tapered sleeve type)
6. Torque wrench
7. Engine oil or light grease

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clamp piston and rod assembly in a vise, and remove rod bolts and cap from connecting rod.
2. Install correct size rod bearings into connecting rod and cap.

   (NOTE: Check to see that oil holes align with bearing and connecting rod.)
3. Lubricate the rod bearing with engine oil or light grease.
4. Lubricate rings and piston with engine oil or light grease.
5. Lubricate the inside diameter of the cylinder liner.
6. Lubricate inside diameter of the tapered sleeve type ring compressor.
7. Rotate the crankshaft until the rod journal for the cylinder you are working with is at bottom dead center.

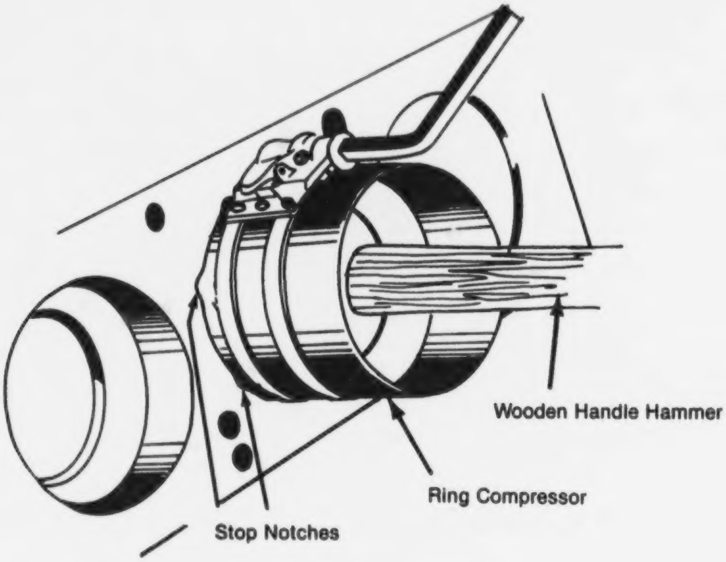
   (NOTE: Check to be sure you install pistons and rods into the correct cylinders.)

JOB SHEET #7

8. Install tapered sleeve ring compressor over cylinder; install piston and rod assembly.

9. Using a firm, steady push, install piston assembly into the cylinder. (Figure 1)

FIGURE 1



10. Guide the large end of the rod onto the crankshaft journal.

    Obtain instructor's initials here ____________ before proceeding to next step.

11. Lubricate bearing in rod cap with engine oil or light grease.

12. Check rod bearing clearance with Plastigage®.

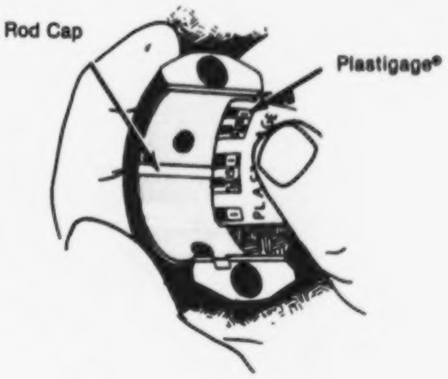
    a. Place Plastigage® on the rod journal or in rod cap on the bearing.

JOB SHEET #7

b. Install rod cap and torque to specification.

c. Remove the rod cap and compare the width of the Plastigage® with various widths on the Plastigage® package. (Figure 2)

FIGURE 2

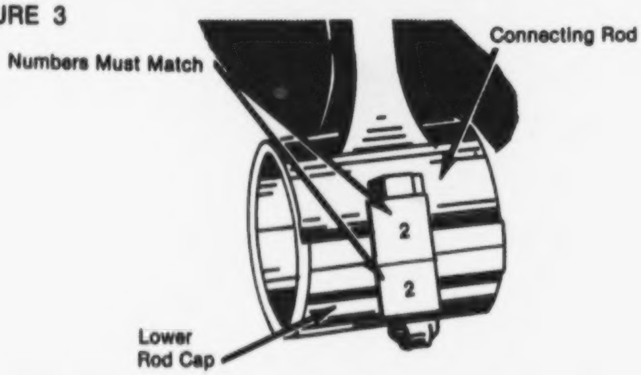

Rod Cap
Plastigage®

(NOTE: Check manufacturer's specification for correct bearing clearance.)

Obtain instructor's initials here ____________ before proceeding to next step.

13. Reinstall the rod cap onto the connecting rod. (Figure 3)

FIGURE 3


Numbers Must Match
Connecting Rod
2
2
Lower Rod Cap

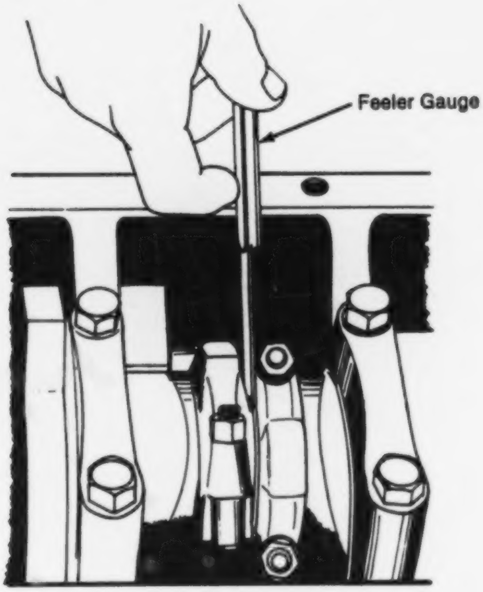
(NOTE: Make sure the numbers on rod and cap match and appear on the same side.)

JOB SHEET #7

14. Torque rod cap bolts to specifications.

15. Check side clearance between connecting rod and crank journal flange with a feeler gauge. (Figure 4)

FIGURE 4



16. Rotate crankshaft after each rod and piston assembly has been installed to make sure it moves freely.

17. Recheck all torques after all pistons have been installed.

Obtain instructor's initials here ____________.

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #1 — REMOVE PISTON AND CONNECTING ROD ASSEMBLY

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used all shop safety precautions.	______	______
3. Removed cylinder head assembly.	______	______
4. Removed carbon ridge from liner.	______	______
5. Removed oil pan.	______	______
6. Positioned piston at bottom dead center.	______	______
7. Removed rod cap and rod bearing.	______	______
8. Installed guide pins.	______	______
9. Pushed piston out of cylinder.	______	______
10. Removed piston and rod assembly.	______	______
11. Tagged connecting rod and cap.	______	______
12. Placed rod and piston assembly in a container.	______	______
13. Checked in/put away tools and materials.	______	______
14. Cleaned the work area.	______	______
15. Used proper tools correctly.	______	______
16. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
17. Practiced safety rules throughout procedure.	______	______
18. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Piston and rod assembly are removed.	4	3	2	1
Piston and rod assembly are tagged.	4	3	2	1
Piston and rod assembly are placed in a container to protect them.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #2 — REMOVE PISTON RINGS AND PISTON FROM ROD

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used all shop safety precautions.	______	______
3. Removed rings from piston.	______	______
4. Removed piston from rod.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Rings are removed from piston.				
	4	3	2	1
Piston is removed from connecting rod.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #3 — CLEAN PISTONS

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used all shop safety precautions.	______	______
3. Allowed pistons to soak.	______	______
4. Washed pistons in soapy solution.	______	______
5. Steam cleaned pistons.	______	______
6. Dried pistons with compressed air.	______	______
7. Cleaned pistons with glass bead.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Piston is cleaned properly.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #4 — INSPECT AND MEASURE PISTONS FOR WEAR

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used all shop safety precautions.	______	______
3. Inspected piston for damage.	______	______
4. Measured ring grooves with feeler gauge.	______	______
5. Measured ring grooves with wear gauge.	______	______
6. Measured piston for wear.	______	______
7. Measured piston to cylinder clearance.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Ring grooves are within specification.	4	3	2	1
Pistons are within specification.	4	3	2	1
Piston to cylinder clearance is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #5 — INSPECT CONNECTING ROD

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned connecting rod.	______	______
4. Inspected rod for twists or bends.	______	______
5. Measured small bore rod diameter.	______	______
6. Measured large bore rod diameter.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Connecting rod meets specification.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

- 4 — Skilled — Can perform job with no additional training.
- 3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
- 2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
- 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #6 — ASSEMBLE PISTON TO ROD AND INSTALL RINGS

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Used shop safety precautions.	______	______
3.	Installed piston onto rod.	______	______
4.	Installed piston pin retainer.	______	______
5.	Installed rings onto pistons.	______	______
6.	Checked in/put away tools and materials.	______	______
7.	Cleaned the work area.	______	______
8.	Used proper tools correctly.	______	______
9.	Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10.	Practiced safety rules throughout procedure.	______	______
11.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Piston is installed onto connecting rod.				
	4	3	2	1
Piston rings are installed onto piston.				

EVALUATOR'S COMMENTS: ________________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

PRACTICAL TEST
JOB SHEET #7 — INSTALL PISTON AND CONNECTING ROD ASSEMBLY INTO CYLINDER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed bearing into rod.	______	______
4. Lubricated rod bearing.	______	______
5. Lubricated rings and piston.	______	______
6. Lubricated inside diameter of cylinder liner.	______	______
7. Lubricated inside diameter of ring compressor.	______	______
8. Installed piston assembly into cylinder.	______	______
9. Checked rod bearing clearance.	______	______
10. Reinstalled rod cap and torqued to specification.	______	______
11. Checked rod side clearance.	______	______
12. Checked in/put away tools and materials.	______	______
13. Cleaned the work area.	______	______
14. Used proper tools correctly.	______	______
15. Performed steps in a timely manner. (____hrs. ____min. ____sec.)	______	______
16. Practiced safety rules throughout procedure.	______	______
17. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Piston is installed correctly.	4	3	2	1
Rod bearing clearance is within specification.	4	3	2	1
Rod side clearance is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

NAME ______________________ SCORE ____________________

TEST

1. Match terms related to piston and connecting rod assemblies with the correct definitions.

_____a. Outside part of piston below ring grooves

_____b. Area between ring grooves

_____c. Ties piston and rod together

_____d. Hole in piston which supports piston pin

_____e. Combustion gases escaping to the crankcase

_____f. Overloading, causing unusual stress

_____g. Glowing or burning

_____h. A groove machined in the piston which holds the piston ring

_____i. The amount of clearance between the split ends of the piston rings

_____j. A fastening device located in the piston pin boss which holds the piston pin in place

_____k. A piston that is ground slightly oval but becomes round when heated

_____l. Holes drilled through the piston wall which allow the oil to escape after the oil-control rings wipe it off the cylinder wall

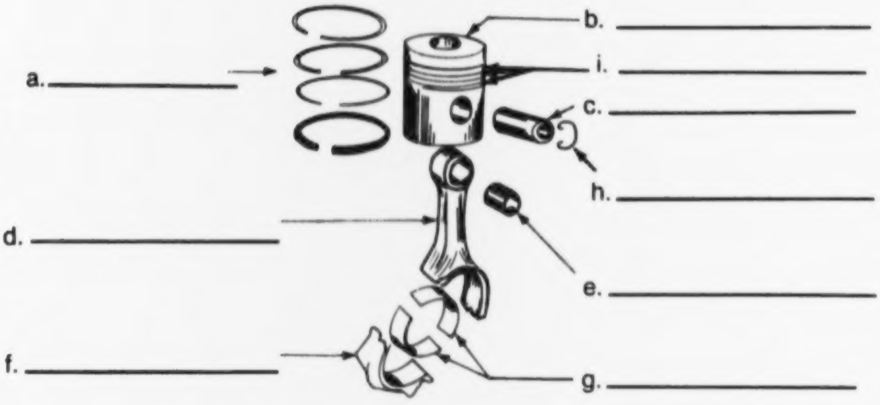
_____m. A rod which joins the piston with the crankshaft.

_____n. Split rings which are expanded and placed into the grooves of the piston.

1. Blow-by
2. Cam ground piston
3. Connecting rod
4. Incandescent
5. Lugging
6. Piston oil holes
7. Piston pin
8. Piston pin boss
9. Piston pin retainer
10. Piston rings
11. Ring end gap
12. Piston ring groove
13. Piston ring land
14. Piston skirt

TEST

2. Identify seven primary parts of a piston and connecting rod assembly.



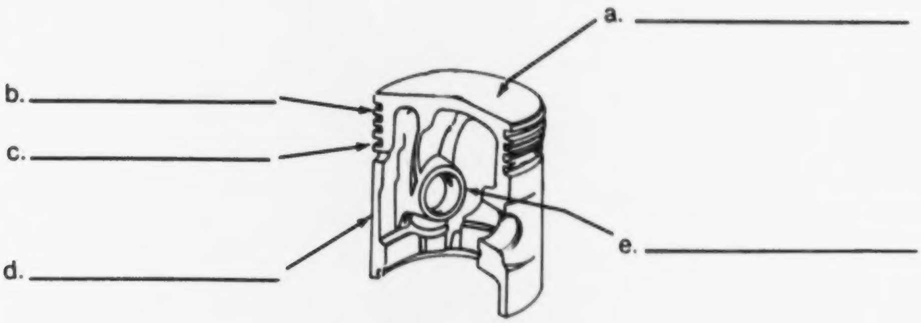
3. List three functions of the piston.

a. ____________

b. ____________

c. ____________

4. Identify five main parts of a piston.



TEST

5. Select the functions of the piston rings by placing an "X" next to the function(s).

______a. Receives the force of combustion

______b. Controls lubrication between piston and cylinder wall

______c. Helps cool the piston by transferring heat

______d. Transmits this force to the crankshaft

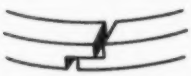
______e. Forms a gas tight seal between the piston and cylinder

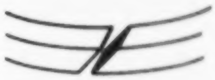
6. Name the two types of piston rings.

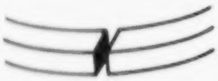
a. ____

b. ____

7. Identify three common types of ring end gaps.







a. ____________________ b. ____________________ c. ____________________

8. Select possible causes of high oil consumption and blow-by by placing an "X" next to the cause(s).

______a. Piston rings installed wrong

______b. Plugged oil ring

______c. Stuck oil ring

______d. Burned exhaust valve

______e. Overall wear in piston, rings, and cylinder

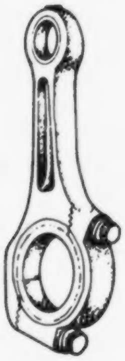
9. Name two types of piston pins.

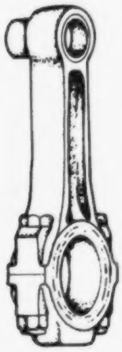
a. ____

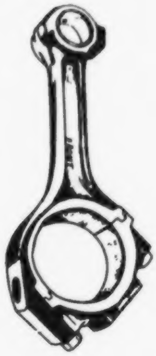
b. ____

TEST

10. Identify three types of construction for the cap end of a connecting rod.







a. ____________________ b. ____________________ c. ____________________

11. Complete the following list of statements concerning the reasons for markings on the connecting rod, piston, and bearing cap.

Example: On the piston — To install in same cylinder and on same side from which removed

a. On the connecting rod — ____

____

b. On the bearing cap — ____

____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

12. Demonstrate the ability to:

a. Remove piston and connecting rod assembly. (Job Sheet #1)

b. Remove piston rings and piston from rod. (Job Sheet #2)

c. Clean pistons. (Job Sheet #3)

d. Inspect and measure pistons for wear. (Job Sheet #4)

e. Inspect connecting rod. (Job Sheet #5)

f. Assemble piston to rod and install rings. (Job Sheet #6)

g. Install piston and connecting rod assembly into cylinder. (Job Sheet #7)

PISTON AND CONNECTING ROD ASSEMBLIES
UNIT III-B

ANSWERS TO TEST

1. a. 14
   b. 13
   c. 7
   d. 8
   e. 1
   f. 5
   g. 4
   h. 12
   i. 11
   j. 9
   k. 2
   l. 6
   m. 3
   n. 10

2. a. Piston rings
   b. Piston
   c. Piston pin
   d. Connecting rod
   e. Piston pin bushing
   f. Connecting rod cap
   g. Bearing shells
   h. Piston pin retainer
   i. Piston ring groove

3. a. Receives force of combustion
   b. Transmits this force to the crankshaft
   c. Carries the piston rings which seal and wipe the cylinder

4. a. Head or crown
   b. Lands
   c. Ring grooves
   d. Skirt
   e. Piston pin boss

5. b, c, e

6. a. Compression
   b. Oil control

7. a. Step
   b. Angle
   c. Butt

8. a, b, c, e

ANSWERS TO TEST

9. a. Semi-floating
   b. Full floating

10. a. Angle cut
    b. Square cut
    c. Tongue and groove

11. a. To install in same cylinder and on same side from which removed
    b. To install on same rod and on same side from which removed

12. Performance skills evaluated to the satisfaction of the instructor

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify primary parts of a camshaft and parts in a valve train. The student should also be able to remove, service, and install a camshaft. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to camshafts and gears with the correct definitions.
2. Name parts on some diesel engines that are actuated by the camshaft.
3. Identify primary parts of a camshaft.
4. Identify parts in a valve train.
5. Complete statements concerning valve timing on a four-cycle engine.
6. Complete statements concerning valve timing on a two-cycle engine.
7. Identify gears found in a typical gear train.
8. Name gears which are marked in the gear train to insure correct valve timing.
9. Identify methods of driving the camshaft.

OBJECTIVE SHEET

10. Demonstrate the ability to:

    a. Remove a camshaft. (Job Sheet #1)

    b. Remove camshaft gear. (Job Sheet #2)

    c. Inspect camshaft and bearings. (Job Sheet #3)

    d. Inspect camshaft lobe lift. (Job Sheet #4)

    e. Install a camshaft gear, and install camshaft into engine. (Job Sheet #5)

    f. Adjust valve clearance on a valve-in-head six-cylinder four-cycle engine. (Job Sheet #6)

    g. Remove camshaft from a Detroit diesel engine. (Job Sheet #7)

    h. Inspect camshaft on a Detroit diesel engine. (Job Sheet #8)

    i. Install camshaft in a Detroit diesel engine. (Job Sheet #9)

CAMSHAFTS, *GEAR TRAIN, AND ENGINE TIMING*
UNIT IV-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheets.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets and worksheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

  1. Have students draw different styles of gear set ups.
  2. Have students make a list of different types of timing marks.
  3. Have students make a drawing of their engine timing.
  4. Show different types of camshafts.
  5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Engine Shop Manual.* Columbus, IN: Cummins Engine Company, 1983.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

REFERENCES USED IN DEVELOPING THIS UNIT

C. *Detroit Diesel Service Manual, 92 Series.* Detroit, MI: General Motors, Inc., 1985.

D. *Engine Service Manual.* Peoria, IL: Caterpillar Tractor Company, 1982.

E. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

F. Schulz, Erich. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. Engine Handbook
   McQuay-Norris, Inc.
   1201 Macklind Avenue
   St. Louis, MO 63110

2. *Motor Magazine*
   Motor Publications
   555 West 57th Street
   New York, NY 10019

B. Filmstrips

1. *Timing and Timing Gears* (33 slides and script)
   Caterpillar Tractor Co.
   Literature Orders Section
   1335 S.W. Washington
   Peoria, IL 61602

2. *Diesel Mechanics II: Engine Assembly* (5 filmstrips with cassettes)
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92626-0798

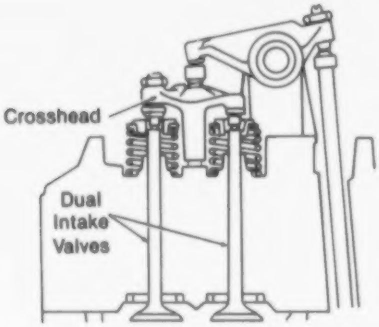
CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

INFORMATION SHEET

I. **Terms and definitions**

A. Backlash — Clearance between meshed gears

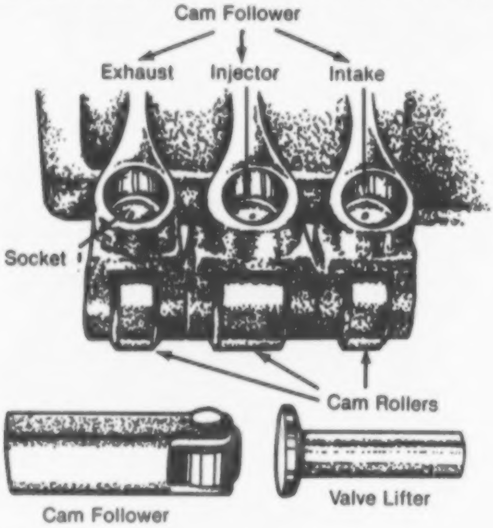
B. Bridge or crosshead — Permits a single rocker arm to depress dual valves


Crosshead
Dual Intake Valves

(Reproduced by permission of Deere & Company, © 1980 Deere & Company. All rights reserved.)

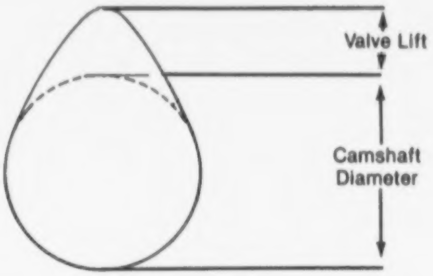
C. Cam followers — Drive the push rods to operate the valves

(NOTE: Cam followers may also be called valve tappets.)

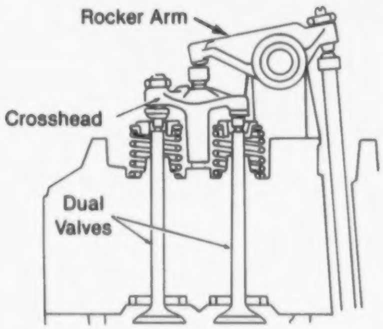

Cam Follower
Exhaust
Injector
Intake
Socket
Cam Rollers
Cam Follower
Valve Lifter

INFORMATION SHEET

D. Cam lobes — Eccentric on the camshaft which changes rotary motion to linear motion (Transparency 1)

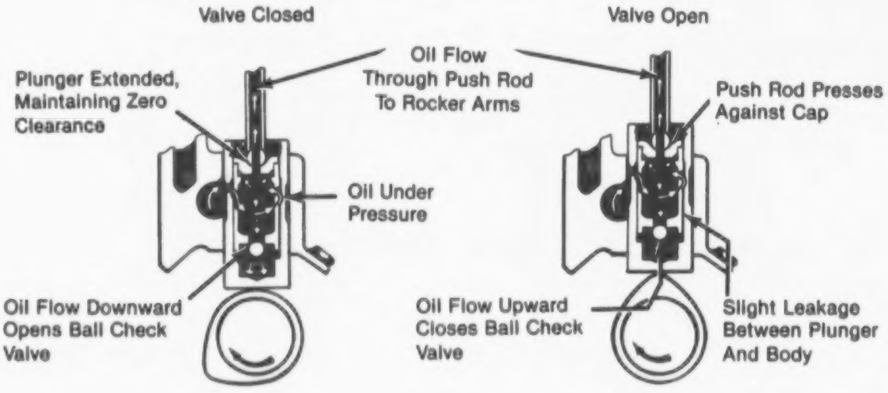

Valve Lift
Camshaft Diameter

E. Dual valves — Two valves operated by a single rocker arm


Rocker Arm
Crosshead
Dual Valves

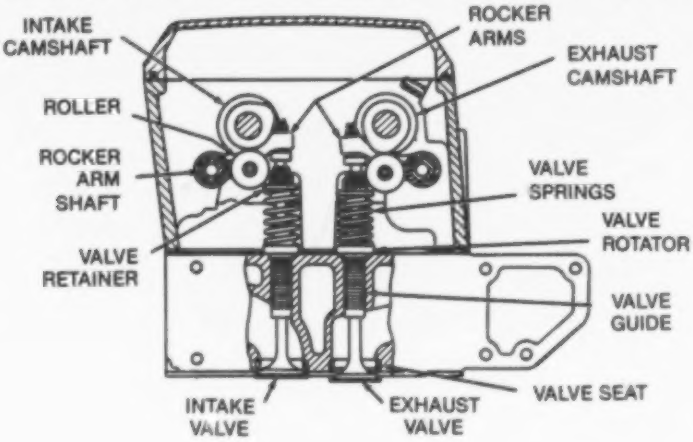
(Reproduced by permission of Deere & Company, © 1980 Deere & Company. All rights reserved.)

F. Hydraulic valve lifters — Noiseless cam followers that automatically adjust for valve clearance (Transparency 2)


Valve Closed
Valve Open
Oil Flow Through Push Rod To Rocker Arms
Plunger Extended, Maintaining Zero Clearance
Push Rod Presses Against Cap
Oil Under Pressure
Oil Flow Downward Opens Ball Check Valve
Oil Flow Upward Closes Ball Check Valve
Slight Leakage Between Plunger And Body

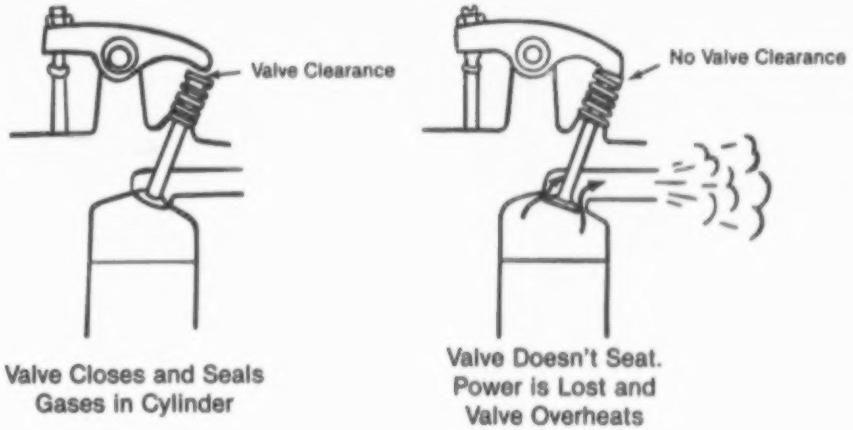
INFORMATION SHEET

G. Overhead cam (OHC) — Engine with the camshaft mounted on cylinder head where it actuates valves directly without pushrods or rocker arms


INTAKE CAMSHAFT
ROCKER ARMS
EXHAUST CAMSHAFT
ROLLER
ROCKER ARM SHAFT
VALVE SPRINGS
VALVE ROTATOR
VALVE RETAINER
VALVE GUIDE
VALVE SEAT
INTAKE VALVE
EXHAUST VALVE

(Courtesy of R. L. Little and G. C. Edmondson, *Diesel Mechanics: An Introduction.* © 1982. PWS-KENT Publishing Company, a division of Wadsworth, Inc.)

H. Valve clearance — Definite clearance between rocker arm and valve stem


Valve Clearance
No Valve Clearance

Valve Closes and Seals Gases in Cylinder

Valve Doesn't Seat. Power is Lost and Valve Overheats

II. **Parts actuated by the camshaft on some diesel engines**

A. Intake valve

B. Exhaust valve

C. Unit injector

D. Air starting valves

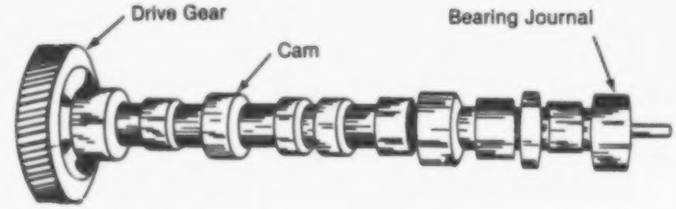
INFORMATION SHEET

III. **Primary parts of a camshaft**

A. Drive gear

B. Cams

C. Bearing journal


Drive Gear
Cam
Bearing Journal

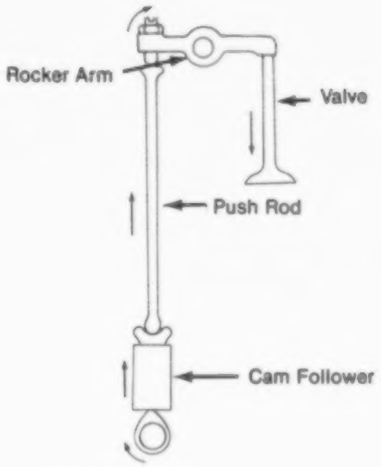
IV. **Parts in a valve train**

A. Valve

B. Rocker arm

C. Push rod

D. Cam follower


Rocker Arm
Valve
Push Rod
Cam Follower

V. **Valve timing on a four-cycle engine**

A. Camshaft turns at one-half the speed of crankshaft.

B. Each intake and exhaust valve is opened and closed once during two revolutions of the crankshaft.

VI. **Valve timing on a two-cycle engine**

A. Camshaft turns at the same speed as crankshaft.

B. Exhaust valve is opened and closed once during one revolution of the crankshaft.

(NOTE: Intake port in cylinder liner is uncovered by the piston once during one revolution of the crankshaft.)

INFORMATION SHEET

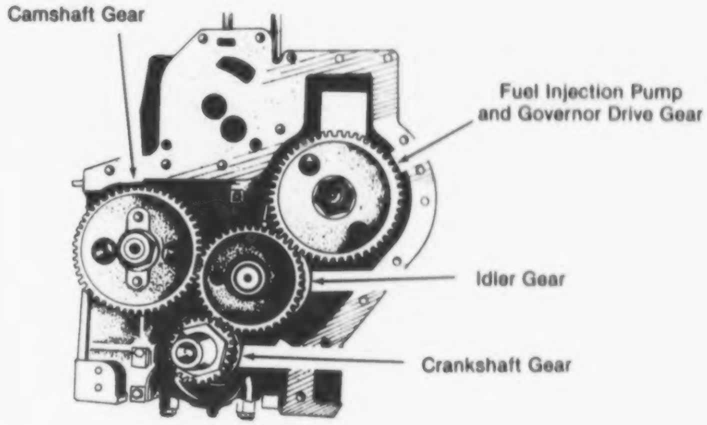
VII. **Gears in a typical gear train**

A. Camshaft gear

B. Crankshaft gear

C. Idler gear

D. Fuel injection pump and governor drive gear

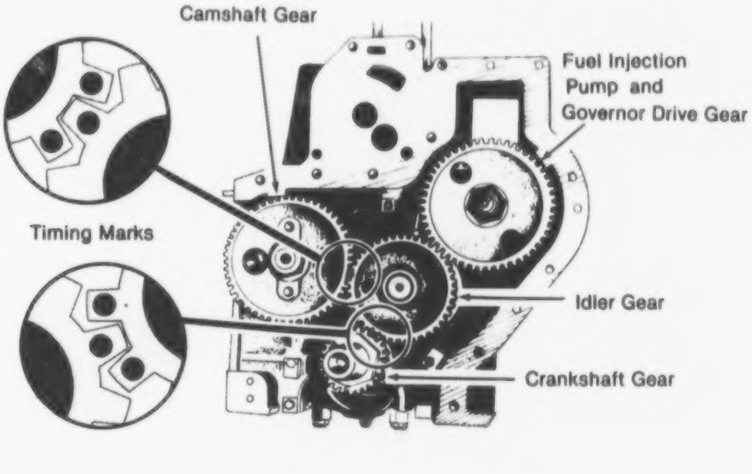

Camshaft Gear
Fuel Injection Pump and Governor Drive Gear
Idler Gear
Crankshaft Gear

VIII. **Gears marked to insure correct valve timing** (Transparency 3)

A. Crankshaft gear teeth

B. Idler gear teeth

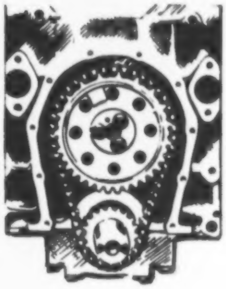
C. Camshaft gear teeth


Camshaft Gear
Fuel Injection Pump and Governor Drive Gear
Timing Marks
Idler Gear
Crankshaft Gear

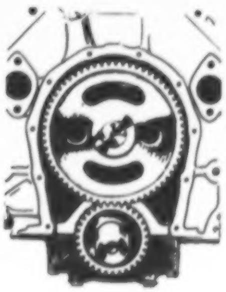
INFORMATION SHEET

IX. Methods of driving the camshaft (Transparency 4)

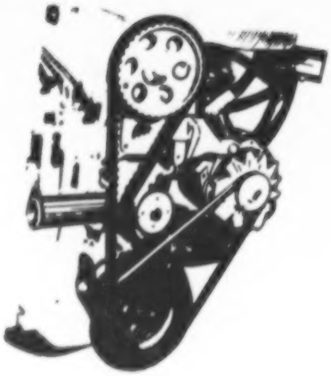
A. Chain



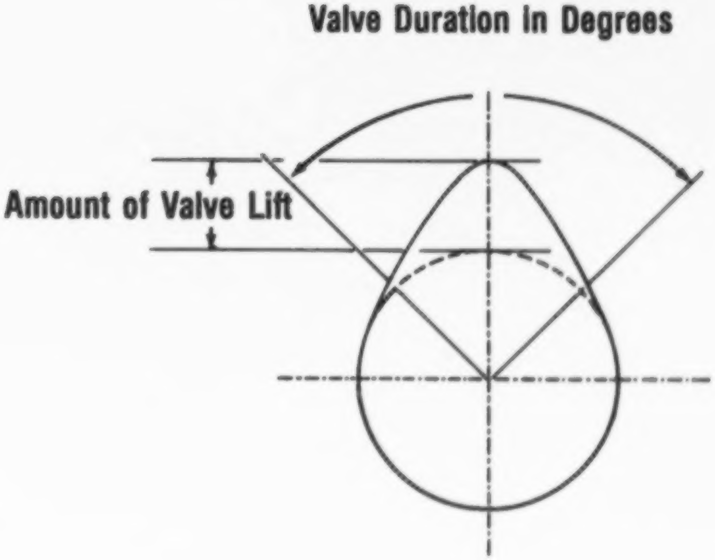
B. Gear

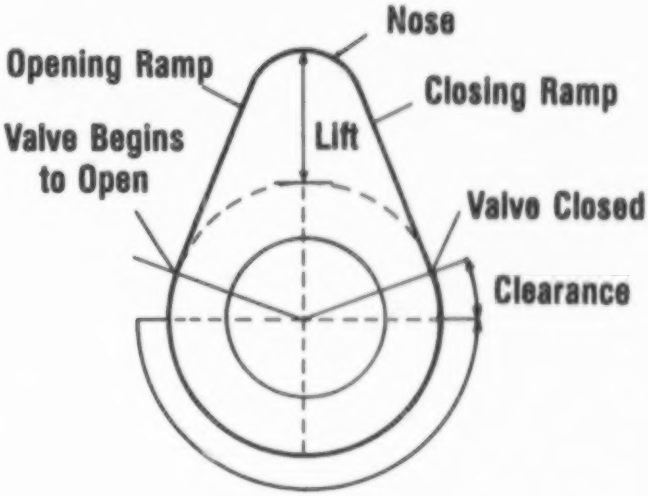


C. Belt

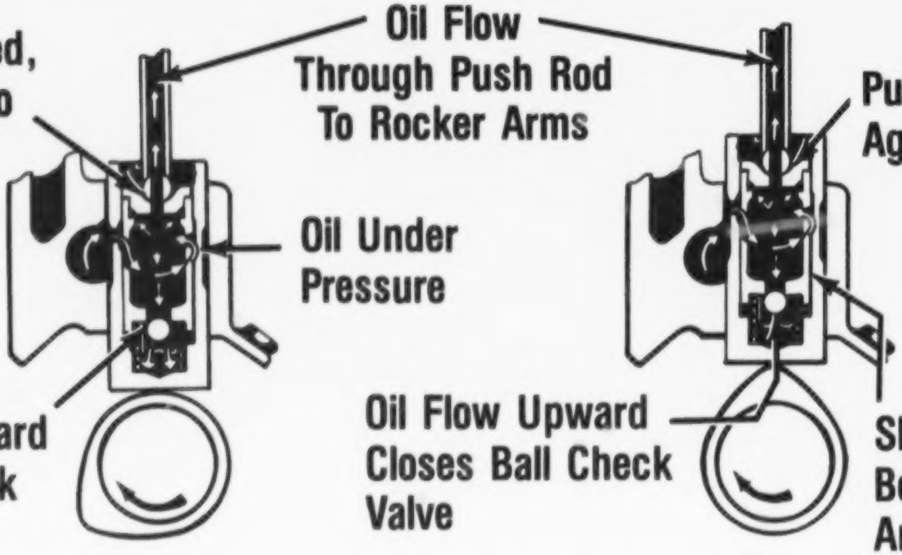


Parts of the Cam Lobe


Valve Duration in Degrees
Amount of Valve Lift


Nose
Opening Ramp
Closing Ramp
Lift
Valve Begins to Open
Valve Closed
Clearance

Operation of a Hydraulic Valve Lifter



Valve Closed

Valve Open

Oil Flow Through Push Rod To Rocker Arms

Plunger Extended, Maintaining Zero Clearance

Oil Under Pressure

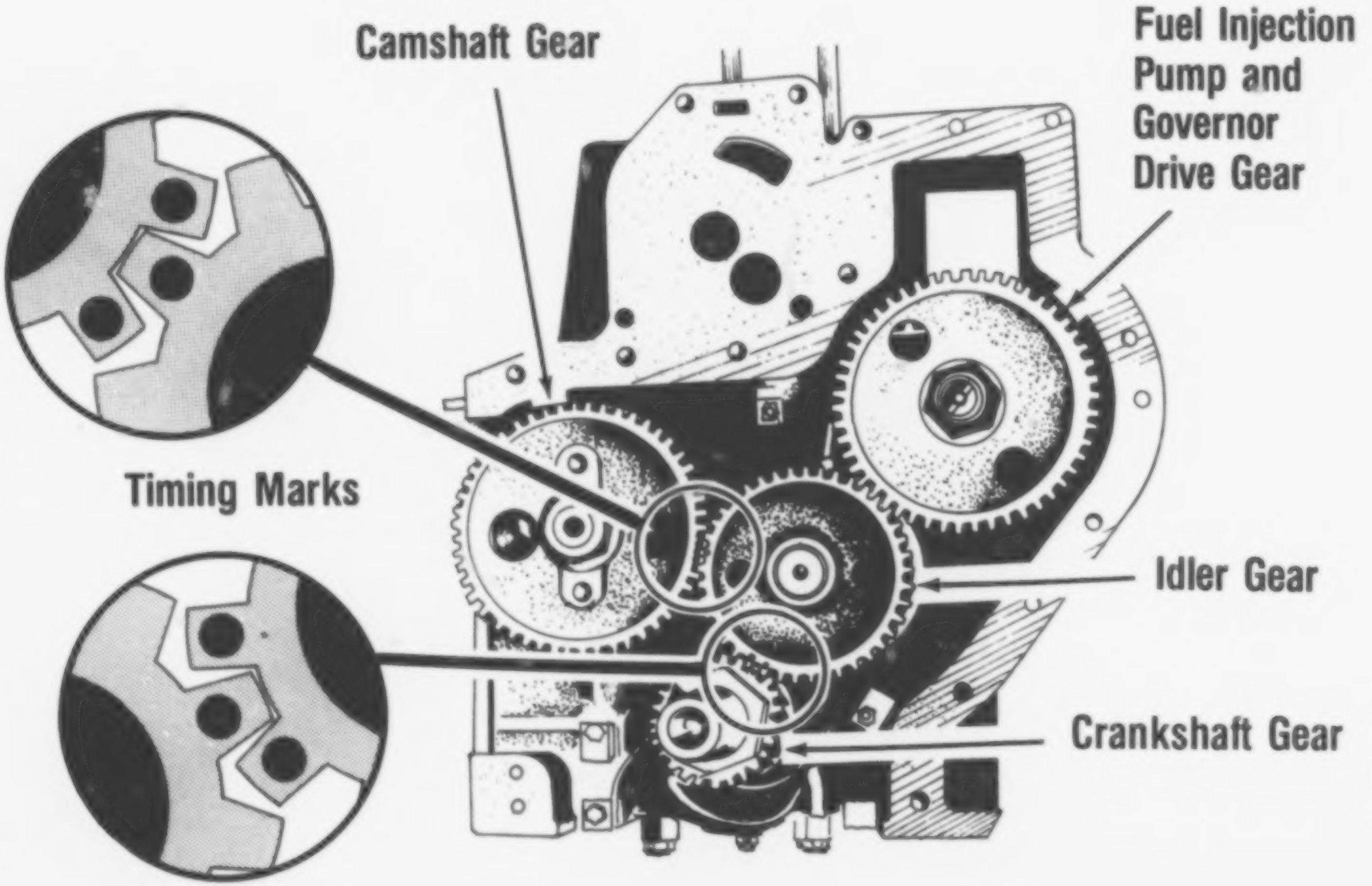
Oil Flow Downward Opens Ball check Valve

Push Rod Presses Against Cap

Oil Flow Upward Closes Ball Check Valve

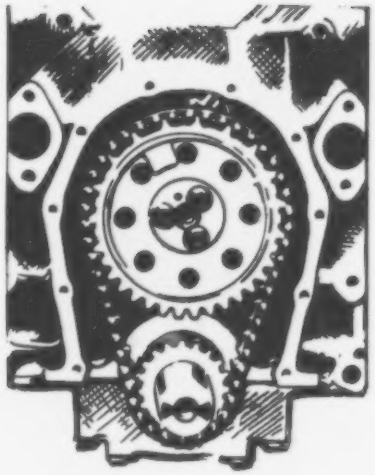
Slight Leakage Between Plunger And Body

Timing Marks on Gear Train

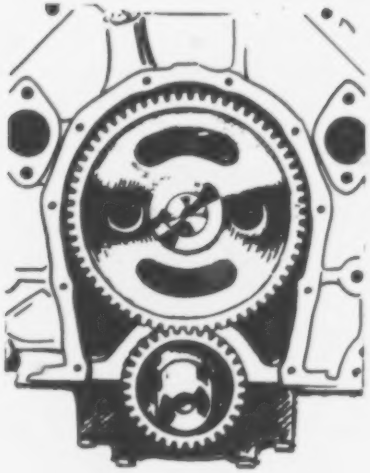

Camshaft Gear
Fuel Injection Pump and Governor Drive Gear
Timing Marks
Idler Gear
Crankshaft Gear

Methods of Driving the Camshaft

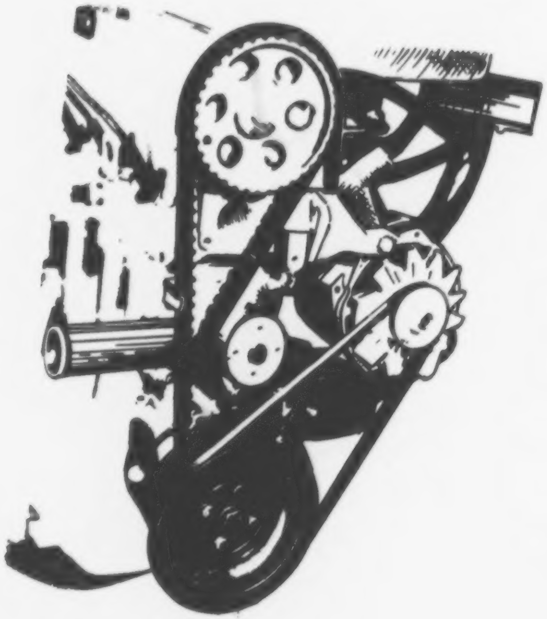
Chain



Gear



Belt



CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #1 — REMOVE A CAMSHAFT

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: It will be necessary to remove rocker arms, push rods, and cam followers before removing camshaft. It may be necessary to remove head in some instances, so check manufacturer's service manual before removing any camshaft.)

1. Remove cam follower housing and gasket from cylinder block. (Figure 1)

FIGURE 1

Cam Follower Housing

JOB SHEET #1

2. Remove front cover housing from engine. (Figure 2)

FIGURE 2

Front Cover Housing

3. Rotate camshaft slowly while pulling the camshaft from the engine. (Figure 3)

(NOTE: Rotating the camshaft during removal permits the lobes of the cam to pass through the camshaft bushings smoothly without damage to either the bushings or the lobes.)

FIGURE 3

4. Remove cam from engine and stand on end; secure to work bench.

Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #2 — REMOVE CAMSHAFT GEAR

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Gear puller
6. Hydraulic press

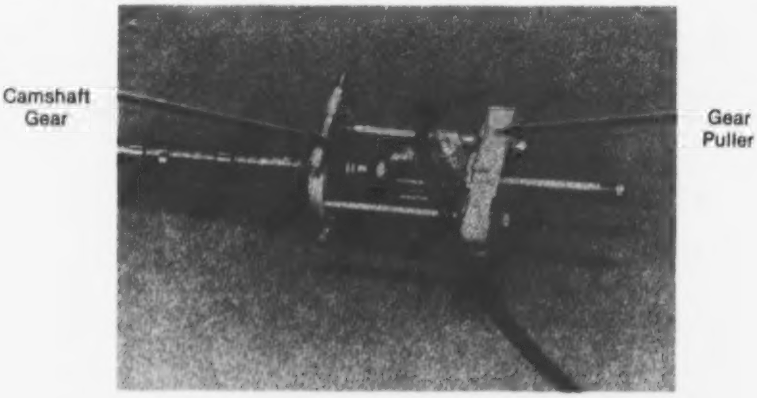
B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Follow manufacturer's specifications before removing any camshaft gear.)

1. Remove camshaft gear from camshaft with a gear puller. (Figure 1)

FIGURE 1



   a. Install a gear puller as shown in Figure 1.

   b. Be careful not to damage camshaft or camshaft gear.

   (NOTE: Be sure to use proper size gear puller.)

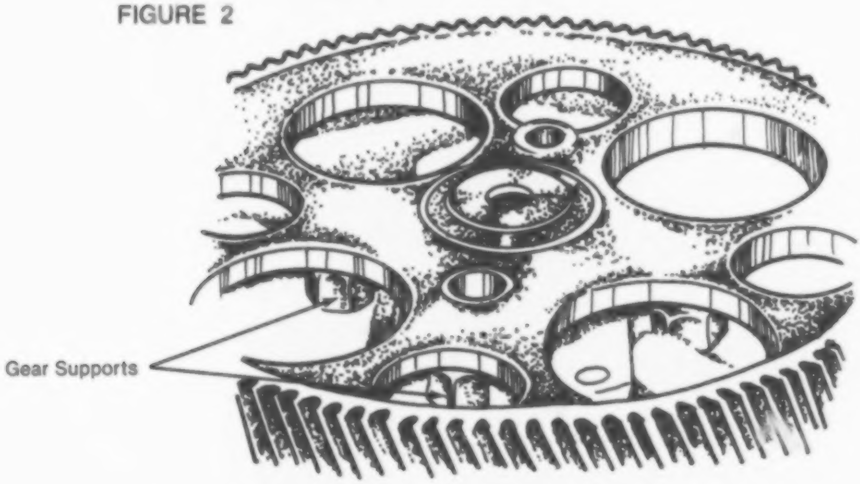
JOB SHEET #2

2. Remove camshaft gear from camshaft with a hydraulic press.

   a. Mount the camshaft and gear in a hydraulic press, and support the gear as close to the hub as possible. (Figure 2)

   (NOTE: To press a shaft from a gear when the gear is supported only at its outer rim may break the gear.)

   FIGURE 2


Gear Supports

   b. Check alignment of press to the camshaft while using press, and do not let camshaft drop to the floor. (Figure 3)

   FIGURE 3

Hydraulic Press
Camshaft
Camshaft Gear

Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #3 — INSPECT CAMSHAFT AND BEARINGS

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Telescoping gauges
6. Outside micrometer
7. "V" blocks
8. Dial indicator

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Before measuring a camshaft or bearing, check the service manual for specifications of camshaft, bearings, and oil clearances; record specifications on Worksheet #1.)

1. Measure inside diameter of a camshaft bearing.

   a. Use a telescoping gauge to measure the inside diameter of the camshaft bearing. (Figure 1)

   FIGURE 1

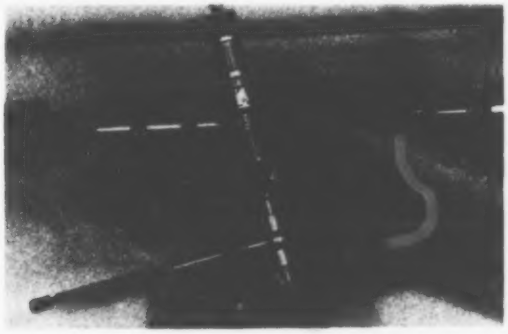
JOB SHEET #3

b. Align telescoping gauge in bearing and lock the legs into position.

c. Remove telescoping gauge from the camshaft bearing.

d. Use an outside micrometer to measure the width of the telescoping gauge. (Figure 2)

FIGURE 2



e. Record the measurement in Column A of Worksheet #1.

f. Measure the remaining camshaft bearings and record the measurements in Column A next to the corresponding camshaft journal.

Obtain instructor's initials here ____________ before proceeding to next step.

2. Measure outside diameter of camshaft bearing journal.

   a. Place the camshaft on "V" blocks to measure the camshaft journals.

JOB SHEET #3

b. Use an outside micrometer to measure the outside diameter of bearing journal. (Figure 3)

FIGURE 3

c. Measure camshaft bearing journal at two locations, and record the measurements in Column B of Worksheet #1.

(NOTE: Take a measurement at diameter 1, then measure 90° from measurement 1 to get diameter. See diagram on Worksheet #1.)

d. Subtract the smallest diameter from the largest diameter in Column B to calculate journal out-of-round; record journal out-of-round in Column C.

e. Subtract the largest diameter in Column B from the bearing measurement in Column A to calculate bearing clearance; record bearing clearance in Column D.

f. Write comments about each bearing journal that is inspected (good, bad, scratched, etc.) in Column E.

g. Measure remaining camshaft bearing journals; calculate out-of-round and bearing clearance.

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #3

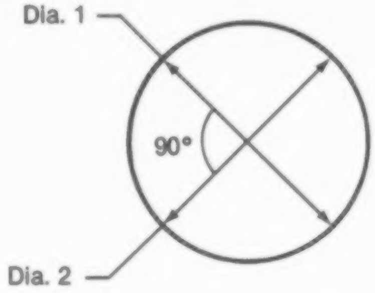
3. Measure camshaft runout.
   - a. Place camshaft on "V" blocks.
   - b. Use a dial indicator to measure runout. (Figure 4)

FIGURE 4

   - c. Put dial indicator on center camshaft journal, and zero dial indicator.
   - d. Rotate camshaft by hand one complete revolution; watch dial indicator.
   - e. Record measurement at bottom of Worksheet #1.
   - f. Have instructor initial Worksheet #1 when completed.

JOB SHEET #3

CAMSHAFT EVALUATION WORKSHEET #1



Engine Model ________
Serial No. ____________

SPECIFICATIONS

Bearing Journal Diameter ________________
Bearing Clearance ________________________
Permissible Clearance ___________________
Permissible Camshaft Runout ______________

	Column A	Column B		Column C	Column D	Column E
Camshaft Journal No.	Bearing Measurements (Inside Dia.)	Journal		Journal Out-Of Round	Bearing Clearance	Comments
		Dia. 1	Dia. 2			
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Camshaft Runout ____________

Instructor's Initials ____________

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #4 — INSPECT CAMSHAFT LOBE LIFT

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Outside micrometer
6. "V" blocks

B. Procedure

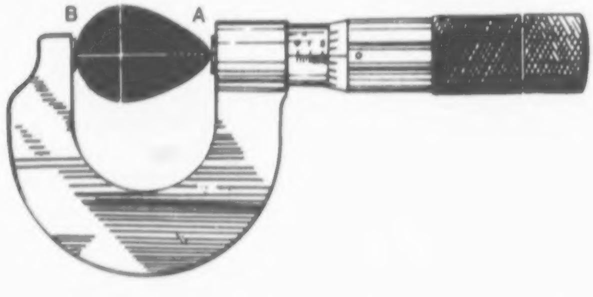
(CAUTION: Follow all shop safety procedures.)

(NOTE: Before measuring camshaft lobe lift, check in service manual for specifications, and record on Worksheet #2. Some manufacturers specify maximum lobe and lift wear; others do not.)

1. Measure camshaft for lobe lift.

   a. Measure the camshaft lobe from point A to point B with an outside micrometer. (Figure 1)

   FIGURE 1

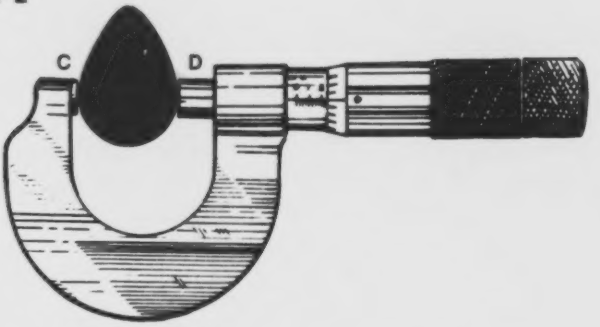


   b. Record the measurement in Column A of Worksheet #2 with the appropriate intake or exhaust valve.

JOB SHEET #4

c. Measure the same camshaft lobe from point C to point D with an outside micrometer. (Figure 2)

FIGURE 2



d. Record the measurement in Column B of Worksheet #2 with the appropriate intake or exhaust valve.

e. Subtract the measurement in Column B from the measurement in Column A to calculate the lobe lift.

f. Record the answer in Column C of Worksheet #2.

g. Visually inspect the lobe, and write any comments on Worksheet #2.

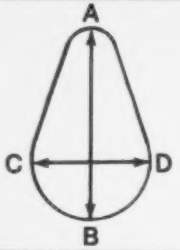
Obtain instructor's initials here ____________ before proceeding to next step.

h. Measure remaining cam lobes, and record with the appropriate intake or exhaust valves.

i. Have instructor initial Worksheet #2 when completed.

JOB SHEET #4

CAMSHAFT EVALUATION WORKSHEET #2



Engine Model ________
Serial No. ____________

SPECIFICATIONS

Lift ______________

Intake Lobe	Column A A-B	Column B C-D	Column C Lobe Lift	Comments
1				
2				
3				
4				
5				
6				
7				
8				
Exhaust Lobe				
1				
2				
3				
4				
5				
6				
7				
8				

Instructor's Initials __________

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #5 — INSTALL A CAMSHAFT GEAR, AND INSTALL CAMSHAFT INTO ENGINE

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Hand tools
4. Appropriate service manual
5. Hydraulic press
6. Light grease
7. Dial indicator

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Install camshaft gear on camshaft.
    a. Install Woodruff key in the end of the camshaft. (Figure 1)

FIGURE 1

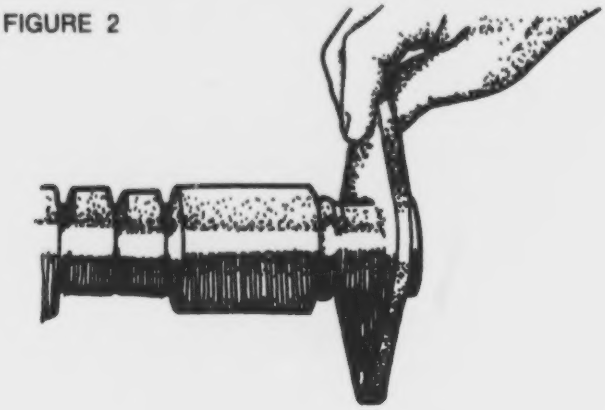
Plastic Hammer
Woodruff Key

(NOTE: Be absolutely certain that you have ordered the correct Woodruff key for the engine being rebuilt. Some manufacturers require an offset key for the camshaft.)

JOB SHEET #5

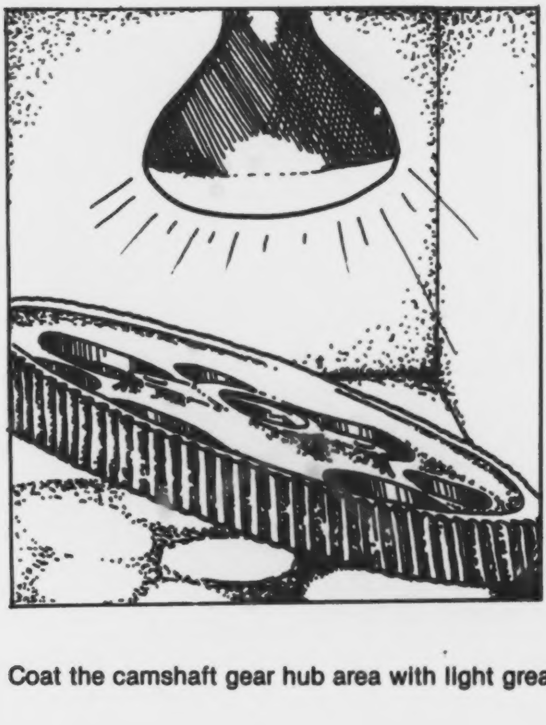
b. Install thrust plate (if used) on camshaft. (Figure 2)

FIGURE 2



c. Heat the camshaft gear in an oven or with electric heat lamps. (Figure 3)

FIGURE 3



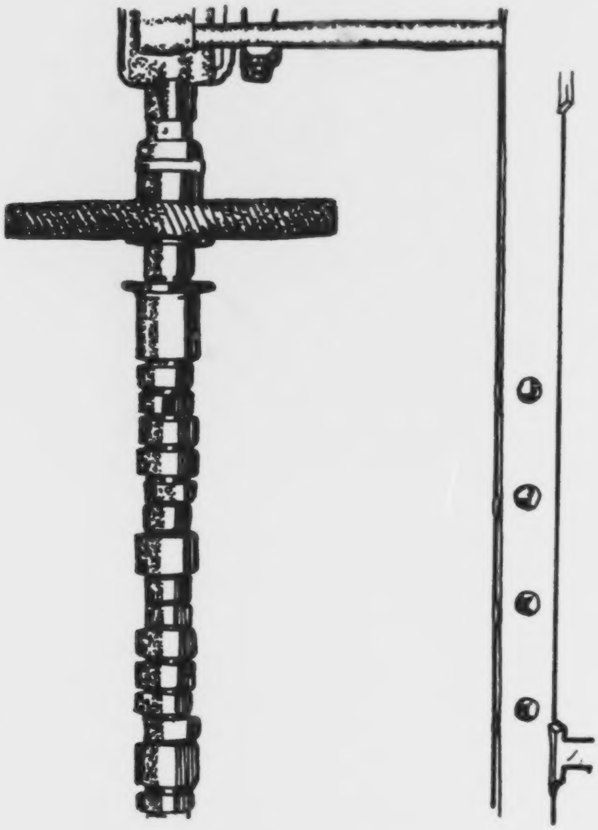
d. Coat the camshaft gear hub area with light grease.

JOB SHEET #5

e. Press the camshaft gear onto the camshaft. (Figure 4)

(NOTE: Make sure the gear is the correct gear for the engine, and that it is being installed in the right direction.)

FIGURE 4



(CAUTION: Put light pressure on gear with hydraulic press; then check alignment of the gear and camshaft.)

d. Remove the camshaft and gear from the hydraulic press.

Obtain instructor's initials here ____________ before proceeding to next step.

2. Install camshaft into engine.

   a. Lubricate the camshaft bearings with a light grease.

   b. Lubricate the cam lobes and bearing journals with a light grease.

JOB SHEET #5

c. Slip the camshaft into place in the engine block with a turning motion so that the lobes of the camshaft will pass freely through the camshaft bearings. (Figure 5)

FIGURE 5

d. Align the timing marks on the camshaft gear with the timing marks of the crankshaft or idler gear as you push in the camshaft the final two or three inches.

e. Align the camshaft retainer (if used) that holds the camshaft in the cylinder block, and tighten bolts.

(NOTE: Some engines have a camshaft retainer while others do not.)

JOB SHEET #5

d. Check gear backlash using a dial indicator. (Figure 6)

FIGURE 6

(NOTE: Check with service manual for backlash specification.)

Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #6 — ADJUST VALVE CLEARANCE ON A VALVE-IN-HEAD SIX-CYLINDER FOUR-CYCLE ENGINE

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Feeler gauge
6. New valve cover gasket

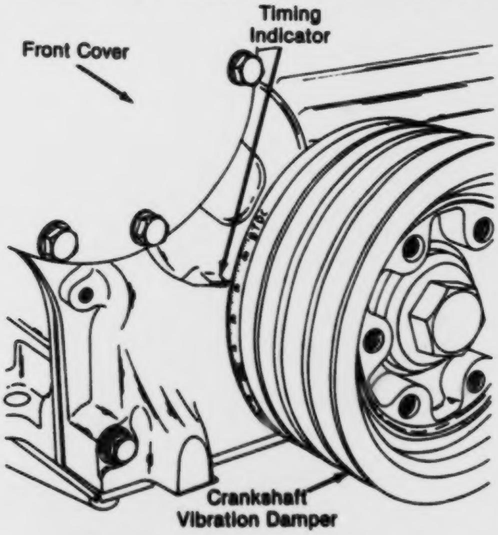
B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: This job sheet describes valve clearance adjustment for most four-cycle engines, but there are many different types. Check with the appropriate service manual before setting the valve.)

1. Clean all dirt and oil from around valve cover, and remove valve cover.
2. Rotate crankshaft in direction of rotation until #1 cylinder is at top dead center (TDC) on the compression stroke.
   a. Align mark on vibration damper or flywheel with timing indicator. (Figure 1)

FIGURE 1



(Courtesy of Deutz-Allis Corporation.)

JOB SHEET #6

b. Turn the push rods on #1 cylinder by hand. If both push rods will turn, the engine is at TDC.

(NOTE: If both push rods do not turn, the engine is not at TDC #1. Rotate crankshaft one complete revolution, and align pointer with mark.)

3. Check with appropriate service manual for the valve clearance recommendations for cold setting and hot setting.

4. Record valve settings on lines below:

Intake	Exhaust
Cold ____________	Cold ____________
Hot ____________	Hot ____________

Obtain instructor's initials here ____________ before proceeding to next step.

5. Determine firing order and mating cylinders.

a. Check with service manual for engine firing order, and record the firing order on the line below:

Firing order ____

(NOTE: In most four-cycle six-cylinder engines, the firing order is 1-5-3-6-2-4.)

b. Write the last three cylinder numbers under the first three on the lines below:

Example: 1-5-3 ____________
6-2-4 ____________

(NOTE: These cylinders are mating cylinders. When #1 is at TDC compression, #6 is at TDC exhaust stroke. The #5 cylinder is 120° before top dead center (BTDC) on compression stroke and #2 cylinder is also 120° BTDC except on exhaust stroke. The #3 cylinder is 120° after top dead center (ATDC) on its intake stroke and #4 is also 120° ATDC on its power stroke.)

6. Adjust the intake and exhaust valves on #1 cylinder, the intake valves of #2 and #4 cylinders, and the exhaust valves of #3 and #5 cylinders.

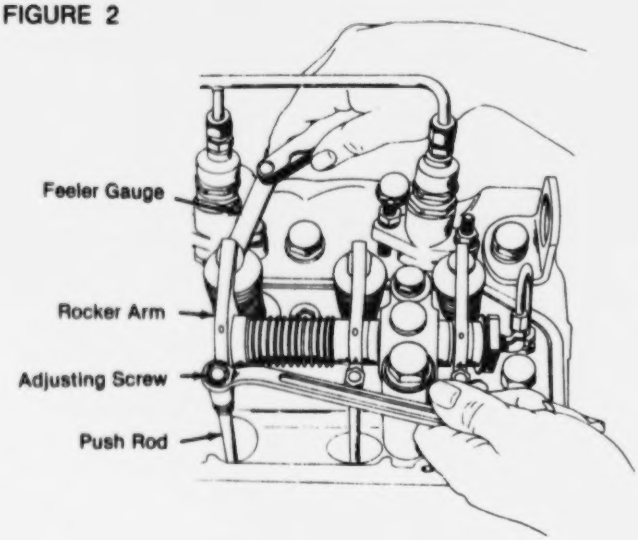
(NOTE: Do not adjust any valves on #6 cylinder.)

JOB SHEET #6

7. Check the valve clearance.

   a. Insert a feeler gauge of the correct thickness between the valve bridge and rocker arm, valve stem and rocker arm, camshaft and follower. (Figure 2)

FIGURE 2



(Courtesy of Deutz-Allis Corporation.)

   b. Adjust to manufacturer's recommendation by loosening lock nut and turning valve adjusting screw up or down with a screwdriver or wrench until there is a light drag on feeler gauge.

   (NOTE: Some manufacturers require the use of go-no-go feeler gauge, so check with service manual.)

8. Rotate crankshaft in direction of rotation one complete revolution until timing marks align again.

9. Adjust the intake and exhaust valves on #6 cylinder; adjust intake valves on #3 and #5 cylinders, and the exhaust valves on #2 and #4 cylinders.

   (NOTE: Do not adjust any valves on #1 cylinder.)

   Obtain instructor's initials here ____________ before proceeding to next step.

10. Replace valve cover gasket.

11. Install valve cover on the engine.

   Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #7 — REMOVE CAMSHAFT FROM A DETROIT DIESEL ENGINE

A. Tools and materials

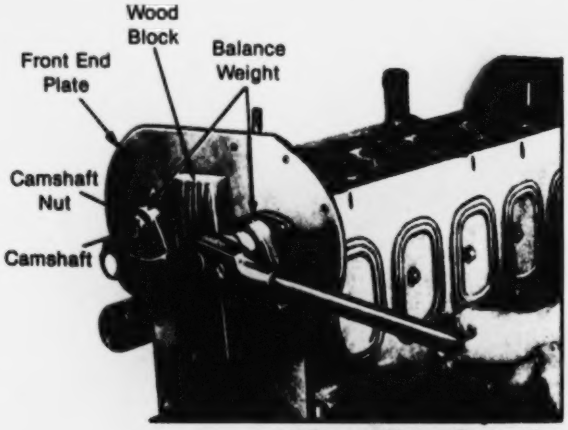
1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Block of wood
6. ³/₄" socket

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Drain the engine cooling system.
2. Remove the cylinder head.
3. Remove the flywheel and flywheel housing.
4. Remove the front balance weight cover.
5. Place a wood block between the balance weights and loosen nut on camshaft. (Figure 1)

FIGURE 1


Wood Block
Front End Plate
Balance Weight
Camshaft Nut
Camshaft

© General Motors Corporation

JOB SHEET #7

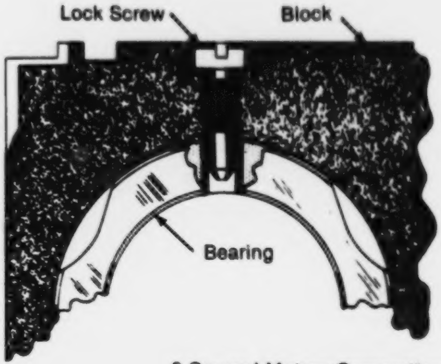
6. Remove the nut and lock washer from the balance weight end of each shaft.

7. Remove the gear nut retaining plates, and remove the gear retaining nuts on the gear end of the camshaft and balance shaft.

8. Remove the front balance weights.

9. Remove the lock screws that secure the camshaft intermediate bearings. (Figure 2)

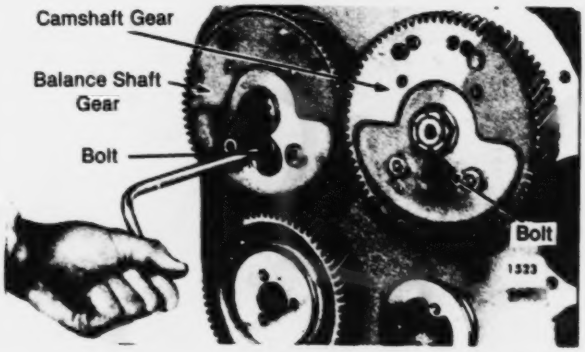
FIGURE 2


Lock Screw
Block
Bearing

© General Motors Corporation

10. Rotate the gears as required to reveal the end bearing retaining bolts, and remove bolts. (Figure 3)

FIGURE 3


Camshaft Gear
Balance Shaft Gear
Bolt
Bolt

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JOB SHEET #7

11. Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear of the cylinder block. (Figure 4)

FIGURE 4

Camshaft Bearing
Camshaft Gear

Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #8 — INSPECT CAMSHAFT ON A DETROIT DIESEL ENGINE

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Feeler gauges

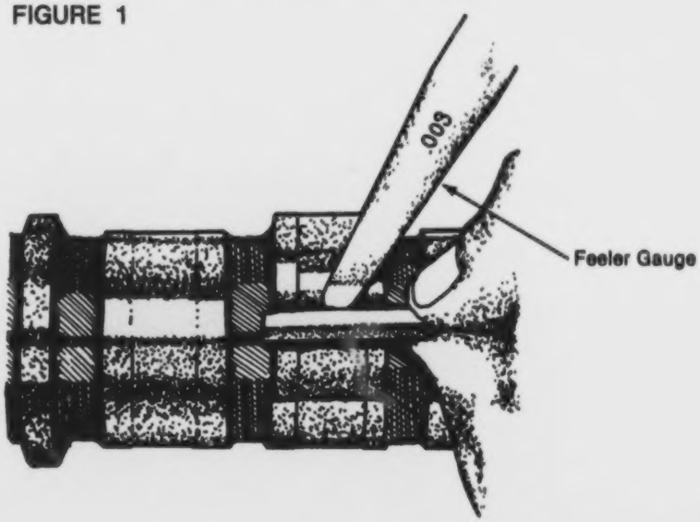
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Check cam lobe wear.

    a. Measure the flat on the injector rise side of cam lobes with a feeler gauge and a piece of square, hard material. (Figure 1)

FIGURE 1



(NOTE: If the flats measure less than .003" in depth and there are no other defects, the camshaft is satisfactory for service.)

JOB SHEET #8

2. Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces; runout should not exceed .002".

3. Examine both faces of the camshaft rear bearing and thrust washer.

4. Examine the surfaces of each camshaft and camshaft gear which contact the thrust washers.

   (NOTE: Replace excessively worn or scored parts.)

   Obtain instructor's initials here ____________.

CAMSHAFT, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

JOB SHEET #9 — INSTALL CAMSHAFT IN A DETROIT DIESEL ENGINE

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Torque wrench

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Install cam bearings on the camshaft.

2. Insert the camshaft into the cylinder block until the camshaft gear teeth almost engage the teeth of the mating gears.

   (CAUTION: Use care when installing the camshaft to avoid damaging the cam lobes.)

3. Align the timing marks on the mating gears and slide the camshaft gear in place.

   (NOTE: Check with service manual for proper timing of the camshaft to the engine. Some engines require an advanced timing, while others require regulator timing.)

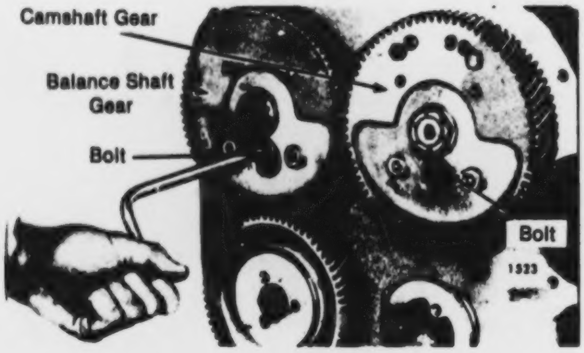
   Obtain instructor's initials here ____________ before proceeding to next step.

4. Rotate the camshaft gear, as required, to install the bolts through the hole in the gear web.

JOB SHEET #9

5. Secure the camshaft rear bearing to the cylinder block with the bolts and lock washers, and tighten to specific torque. (Figure 1)

FIGURE 1



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6. Install balance shaft and align timing marks.

7. Apply grease to the steel face of each thrust washer, then place a thrust washer against the inner end of the camshaft and balance shaft front bearing.

8. Install the camshaft and balance shaft front bearings with the bolts and lock washer, and tighten to specific torque.

   (NOTE: Install the front bearings with care to avoid damaging the thrust washers. **Do not** hammer the bearing into the cylinder block.)

9. Turn the camshaft intermediate bearings until the holes in the bearings are in alignment with the tapped holes in the top of the cylinder block, and tighten to specific torque.

   (NOTE: When the intermediate bearings are locked in position with the lock-screws, the bearings must have slight movement in the block bore.)

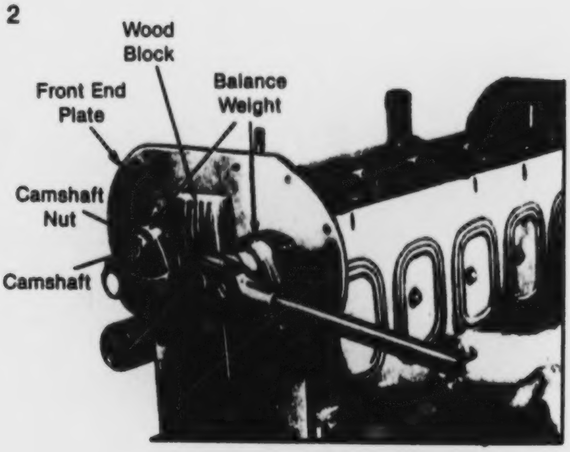
10. Install the front balance weights on the shafts.

11. Place the internal tooth lock washers on the end of each shaft and start the nuts on both shafts.

JOB SHEET #9

12. Use a wood block between the balance weights to prevent turning, and tighten nuts to specific torque. (Figure 2)

FIGURE 2



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13. Install the camshaft and balance shaft gear nut retainers with bolts and lock washers, and tighten to specific torque.

14. Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft.

15. Check the backlash between the mating gears.

    (NOTE: The specified backlash between new gears is .003" to .008" or a maximum of .010" between worn gears.)

16. Install the flywheel housing and other parts or assemblies that were removed from the engine.

17. Install cylinder head and other components.

18. Refill the cooling system.

    Obtain instructor's initials here ____________.

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #1 — REMOVE A CAMSHAFT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.		
2. Used shop safety precautions.		
3. Removed cam follower housing.		
4. Removed front cover housing.		
5. Removed camshaft.		
6. Secured camshaft to work bench.		
7. Checked in/put away tools and materials.		
8. Cleaned the work area.		
9. Used proper tools correctly.		
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)		
11. Practiced safety rules throughout procedure.		
12. Provided satisfactory responses to questions asked.		

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Camshaft is removed from engine.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #2 — REMOVE CAMSHAFT GEAR

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Used shop safety precautions.	_____	_____
3. Used proper size gear puller.	_____	_____
4. Mounted camshaft in hydraulic press correctly.	_____	_____
5. Supported cam gear properly.	_____	_____
6. Checked alignment while pressing gear from shaft.	_____	_____
7. Checked in/put away tools and materials.	_____	_____
8. Cleaned the work area.	_____	_____
9. Used proper tools correctly.	_____	_____
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	_____	_____
11. Practiced safety rules throughout procedure.	_____	_____
12. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Cam gear is removed from camshaft in good condition.				

EVALUATOR'S COMMENTS: ______________________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #3 — INSPECT CAMSHAFT AND BEARINGS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Measured inside diameter of camshaft bearings.	______	______
4. Recorded bearing measurements.	______	______
5. Measured outside diameter of camshaft journal.	______	______
6. Recorded journal measurements.	______	______
7. Recorded journal out-of-roundness.	______	______
8. Recorded bearing clearance.	______	______
9. Measured camshaft runout.	______	______
10. Recorded camshaft runout.	______	______
11. Filled out Worksheet #1.	______	______
12. Checked in/put away tools and materials.	______	______
13. Cleaned the work area.	______	______
14. Used proper tools correctly.	______	______
15. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
16. Practiced safety rules throughout procedure.	______	______
17. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Camshaft bearings are within specification.	4	3	2	1
Camshaft bearing journals are within specification.	4	3	2	1
Camshaft runout is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #4 — INSPECT CAMSHAFT LOBE LIFT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Measured cam lobe at points A and B.	______	______
4. Recorded measurement on Worksheet #2.	______	______
5. Measured cam lobe at points C and D.	______	______
6. Recorded measurement on Worksheet #2.	______	______
7. Recorded cam lobe lift.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Camshaft lobe lift is within specifications.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #5 — INSTALL A CAMSHAFT GEAR AND INSTALL CAMSHAFT INTO ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed key in camshaft. .	______	______
4. Installed camshaft gear onto camshaft.	______	______
5. Lubricated camshaft bearings.	______	______
6. Lubricated cam lobes and bearing journals.	______	______
7. Installed camshaft into engine.	______	______
8. Aligned timing marks on camshaft and crankshaft.	______	______
9. Checked gear backlash.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Camshaft gear is installed properly onto camshaft.	4	3	2	1
Camshaft gear is installed in engine properly.	4	3	2	1
Gear backlash is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #6 — ADJUST VALVE CLEARANCE ON A VALVE-IN-HEAD SIX-CYLINDER FOUR-CYCLE ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned dirt and oil from valve cover.	______	______
4. Aligned timing marks.	______	______
5. Recorded valve settings.	______	______
6. Recorded engine firing order.	______	______
7. Adjusted valves while on TDC compression #1.	______	______
8. Adjusted valves to manufacturer's specification.	______	______
9. Rotated engine one complete revolution and aligned timing marks.	______	______
10. Adjusted valves while engine was at TDC compression #6.	______	______
11. Replaced valve cover gasket.	______	______
12. Installed valve cover on engine.	______	______
13. Checked in/put away tools and materials.	______	______
14. Cleaned the work area.	______	______
15. Used proper tools correctly.	______	______
16. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
17. Practiced safety rules throughout procedure.	______	______
18. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Valves are adjusted on the engine to specifications.				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #7 — REMOVE CAMSHAFT FROM A DETROIT DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Removed the nuts and washers from the camshaft and balance shafts.	______	______
4. Removed front balance weights.	______	______
5. Removed lock screws in camshaft bearings.	______	______
6. Removed bearing retainer bolts.	______	______
7. Removed camshaft from engine.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
The camshaft is properly removed from the engine.				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #8 — INSPECT CAMSHAFT ON A DETROIT DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Checked cam lobes with feeler gauge and square material.	______	______
4. Checked camshaft runout.	______	______
5. Visually inspected camshaft.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #8 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Camshaft lobes are within specifications.	4	3	2	1
Camshaft runout is within specifications.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

PRACTICAL TEST
JOB SHEET #9 — INSTALL CAMSHAFT ON A DETROIT DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed cam bearings.	______	______
4. Installed camshaft into the engine.	______	______
5. Aligned timing marks of the gears.	______	______
6. Installed bearing retainer bolts.	______	______
7. Installed balance shaft.	______	______
8. Installed camshaft front bearings.	______	______
9. Installed camshaft intermediate bearings.	______	______
10. Installed front balance weights.	______	______
11. Torqued nuts on front balance weights.	______	______
12. Checked clearance of the thrust washer.	______	______
13. Checked mating gear backlash.	______	______
14. Installed flywheel.	______	______
15. Installed cylinder head.	______	______
16. Filled cooling system.	______	______
17. Checked in/put away tools and materials.	______	______
18. Cleaned the work area.	______	______
19. Used proper tools correctly.	______	______
21. Performed steps in a timely manner. (____hrs. ____min. ____sec.)	______	______
22. Practiced safety rules throughout procedure.	______	______
23. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #9 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Camshaft bearings are installed properly.	4	3	2	1
Timing marks on gears are aligned.	4	3	2	1
Camshaft is installed into the engine correctly.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms related to camshafts and gears with the correct definitions.

_____a. Eccentric on the camshaft which changes rotary motion to linear motion

_____b. Clearance between meshed gears

_____c. Two valves operated by a single rocker arm

_____d. Drive the push rods to operate the valves

_____e. Noiseless cam followers that automatically adjust for valve clearance

_____f. Definite clearance between rocker arm and valve stem

_____g. Permits a single rocker arm to depress dual valves

_____h. Engine with the camshaft mounted on cylinder head where it actuates valves directly without pushrods or rocker arms

1. Backlash
2. Bridge or crosshead
3. Cam followers
4. Cam lobes
5. Dual valves
6. Hydraulic valve lifters
7. Overhead cam
8. Valve clearance

2. Name three parts on some diesel engines that are actuated by the camshaft.

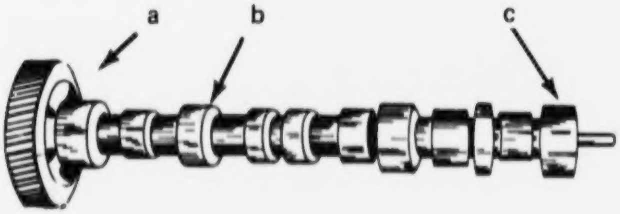
a. ____

b. ____

c. ____

TEST

3. Identify three primary parts of a camshaft.

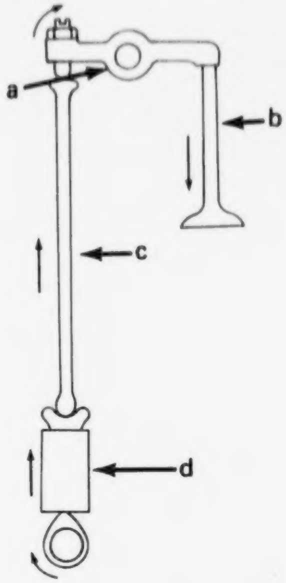


a. ______________________________

b. ______________________________

c. ______________________________

4. Identify four parts in a valve train.



a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

TEST

5. Complete statements concerning valve timing on a four-cycle engine by filling in blanks with the correct word(s).

   a. Camshaft turns at ____________ the speed of crankshaft.

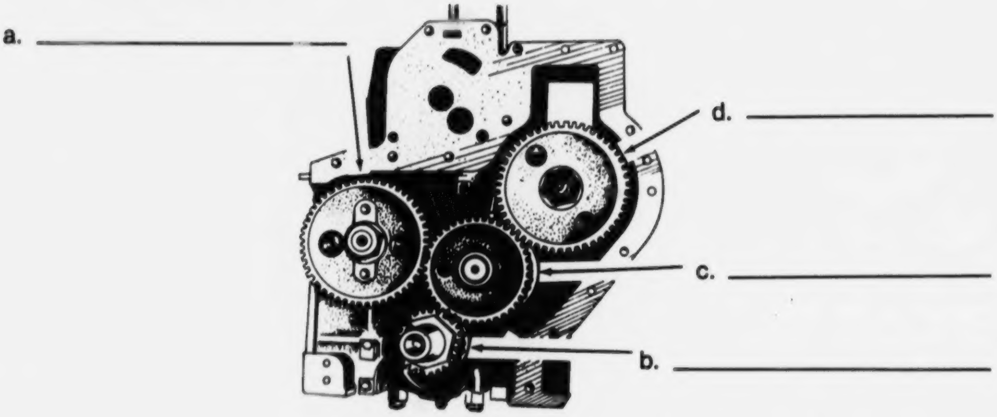
   b. Each intake and exhaust valve is opened and closed once during ____________ revolutions of the crankshaft.

6. Complete statements concerning valve timing on a two-cycle engine by filling in blanks with the correct word(s).

   a. Camshaft turns at ____________ ____________ speed as crankshaft.

   b. Exhaust valve is opened and closed once during ____________ revolution of the crankshaft.

7. Identify four gears found in a typical gear train.



8. Name three gears which are marked in the gear train to insure correct valve timing.

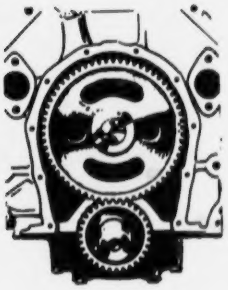
   a. ____

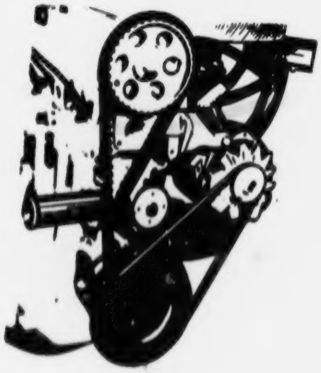
   b. ____

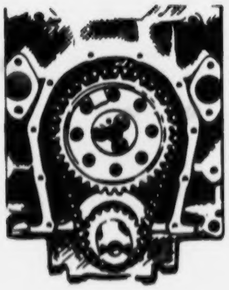
   c. ____

TEST

9. Identify methods of driving the camshaft.







a. ____________________ b. ____________________ c. ____________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

10. Demonstrate the ability to:

    a. Remove a camshaft. (Job Sheet #1)

    b. Remove camshaft gear. (Job Sheet #2)

    c. Inspect camshaft and bearings. (Job Sheet #3)

    d. Inspect camshaft lobe lift. (Job Sheet #4)

    e. Install a camshaft gear, and install camshaft into engine. (Job Sheet #5)

    f. Adjust valve clearance on a valve-in-head six-cylinder four-cycle engine. (Job Sheet #6)

    g. Remove camshaft from a Detroit diesel engine. (Job Sheet #7)

    h. Inspect camshaft on a Detroit diesel engine. (Job Sheet #8)

    i. Install camshaft in a Detroit diesel engine. (Job Sheet #9)

CAMSHAFTS, GEAR TRAIN, AND ENGINE TIMING
UNIT IV-B

ANSWERS TO TEST

1. a. 4
   b. 1
   c. 5
   d. 3
   e. 6
   f. 8
   g. 2
   h. 7

2. Any three of the following:

   a. Intake valve
   b. Exhaust valve
   c. Unit injector
   d. Air starting valves

3. a. Drive gear
   b. Cams
   c. Bearing journal

4. a. Rocker arm
   b. Valve
   c. Push rod
   d. Cam follower

5. a. One-half
   b. Two

6. a. The same
   b. One

7. a. Camshaft gear
   b. Crankshaft gear
   c. Idler gear
   d. Fuel injection pump and governor drive gear

8. a. Crankshaft gear teeth
   b. Idler gear teeth
   c. Camshaft gear teeth

ANSWERS TO TEST

9. a. Gear
   b. Belt
   c. Chain

10. Performance skills evaluated to the satisfaction of the instructor

CYLINDER BLOCKS AND LINERS
UNIT V-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to remove, inspect, and install a cylinder liner from an engine. The student should also be able to inspect a cylinder block. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to a cylinder block with the correct definitions.
2. Identify types of cylinder block construction.
3. Name two advantages a removable liner has over an integral cylinder bore.
4. Match the types of liners with statements on wet and dry liners.
5. Demonstrate the ability to:
    a. Remove a cylinder liner. (Job Sheet #1)
    b. Clean and inspect a cylinder liner. (Job Sheet #2)
    c. Clean and inspect a cylinder block. (Job Sheet #3)
    d. Install cylinder liner into cylinder block and check liner protrusion. (Job Sheet #4)

CYLINDER BLOCKS AND LINERS
UNIT V-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheets and worksheets.

F. Discuss information sheets and worksheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Have students list the different types of liners.
   2. Have students visit different shops to see the block designs.
   3. Show film on block cleaning.
   4. Show various types of damaged cylinder liners.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Caterpillar 3406 Service Manual.* Peoria, IL: Caterpillar Tractor Co., 1982.

B. *Cummins Engine Company Shop Manual.* Columbus, IN: Cummins Engine Company, Inc., 1974.

C. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

D. *Detroit Diesel Service Manual, 92 Series.* Detroit, MI: General Motors Corp., 1985.

E. *Mack Highway Vehicle Service Manual.* Allentown, PA: Mack Truck, Inc., 1982.

F. Schulz, Erich. *Diesel Mechanics.* 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Filmstrip

1. *Cylinder Block Counterboring & Cylinder Liner Pulling and Installation*
   Video tape 43, 45 minutes
   Caterpillar Tractor Co.
   Literature Orders Section
   1335 S.W. Washington
   Peoria, IL 61602

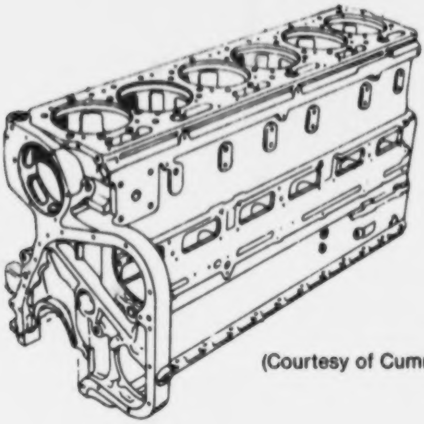
2. *Mack 6 Cylinder Engine Rebuild — Part 1 and 2*
   Mack Trucks, Inc.
   Educational Communications Inc.
   Department M
   761 Fifth Avenue
   King of Prussia, PA 19406

CYLINDER BLOCKS AND LINERS
UNIT V-B

INFORMATION SHEET

I. **Cylinder block terms and definitions**

A. Block — Stationary part that gives the engine form and shape, and furnishes a foundation for the moving parts



(Courtesy of Cummins Engine Company, Inc.)

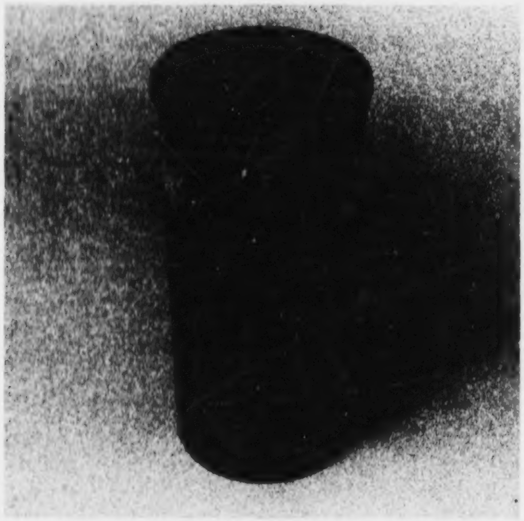
B. Counterbore — Lip cut in top of block into which the cylinder sleeve is fitted.

Counterbore

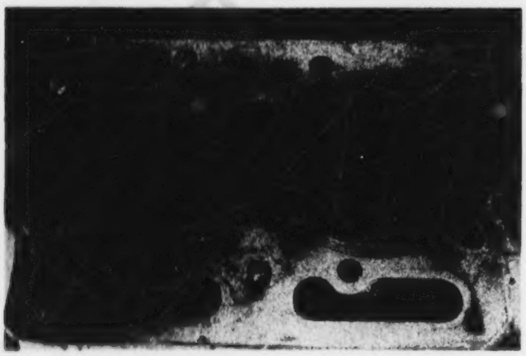
C. Cylinder liner — Sleeve inserted into the bore of the engine block to form the cylinder walls

INFORMATION SHEET

D. Dry liner — Cylinder sleeve inserted into a block bore that makes no contact with the coolant system



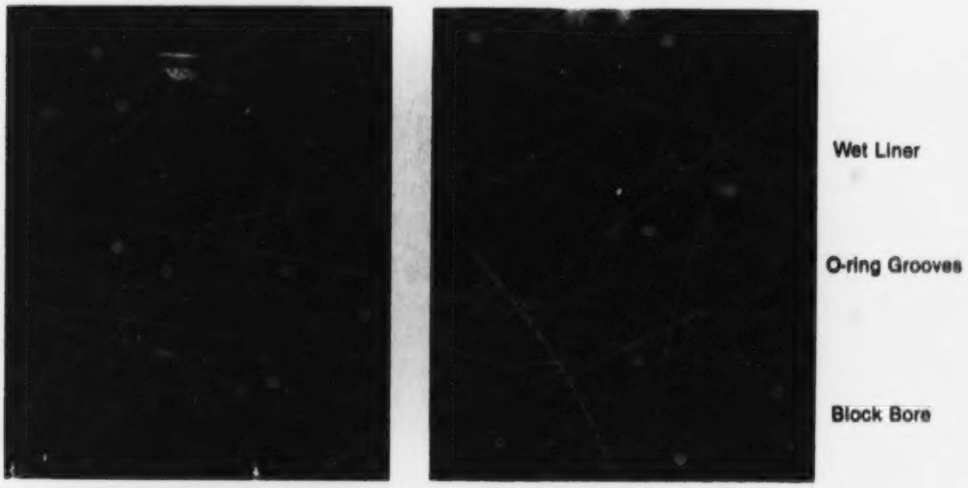
E. Integral cylinder — Cylinder and water jacket cast into the block; does not use cylinder liners



F. Protrusion — Distance the liner stands out or protrudes above the block top deck surface after installation

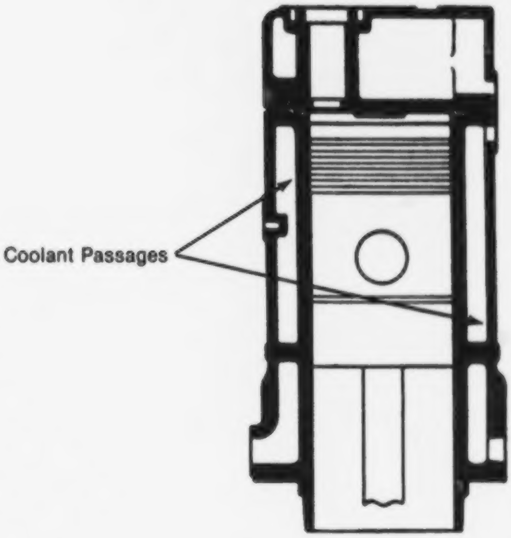
INFORMATION SHEET

G. Wet liner — Cylinder sleeve inserted into a block bore to form part of the water jacket


Wet Liner
O-ring Grooves
Block Bore

II. **Cylinder block construction** (Transparency 1)

A. Cylinder bore an integral part of block

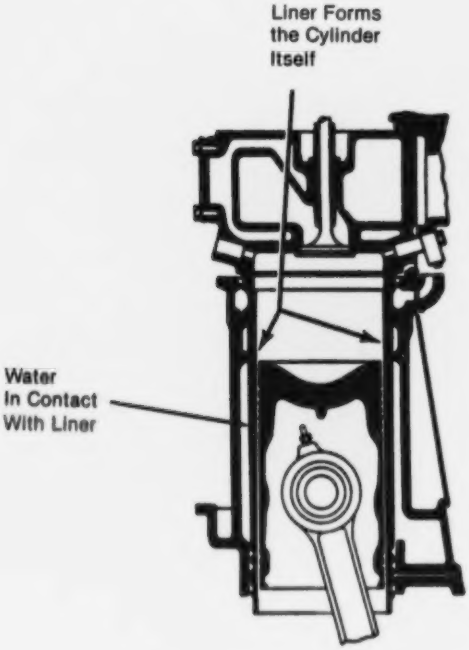

Cylinder Cast as One Piece

Coolant Passages

Integral

INFORMATION SHEET

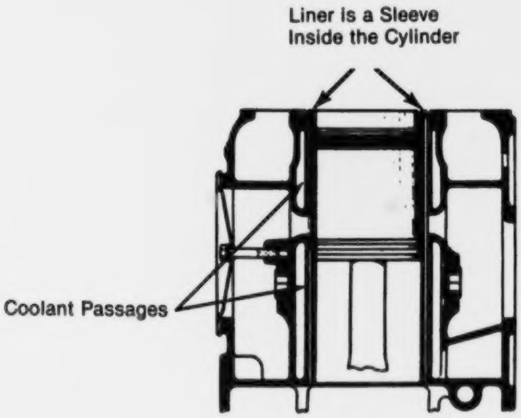
B. Cylinder bore with removable wet liner


Liner Forms
the Cylinder
Itself
Water
In Contact
With Liner

Wet Cylinder Liner

INFORMATION SHEET

C. Cylinder bore with removable dry liner


Liner is a Sleeve
Inside the Cylinder
Coolant Passages

Dry Cylinder Liner

III. **Advantages of removable liner over integral cylinder bore**

A. Allows room for expansion lengthwise

B. May be replaced separately when worn

IV. **Wet and dry liners** (Transparency 2)

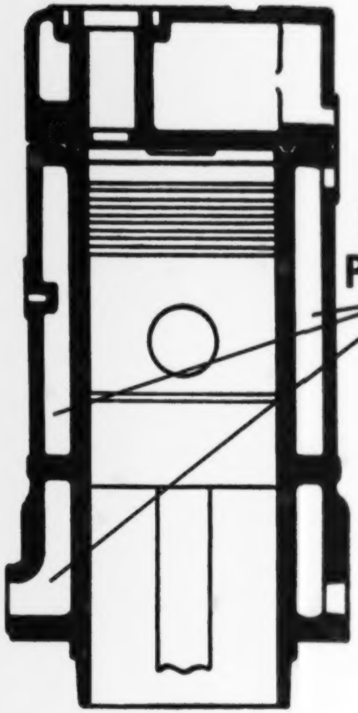
A. Wet liner

1. Provides better cooling of cylinder
2. May be replaced separately when worn

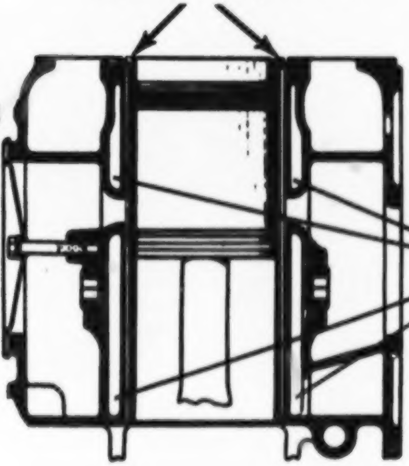
B. Dry liner

1. Less expensive
2. Allows room for expansion lengthwise
3. May be replaced separately when worn

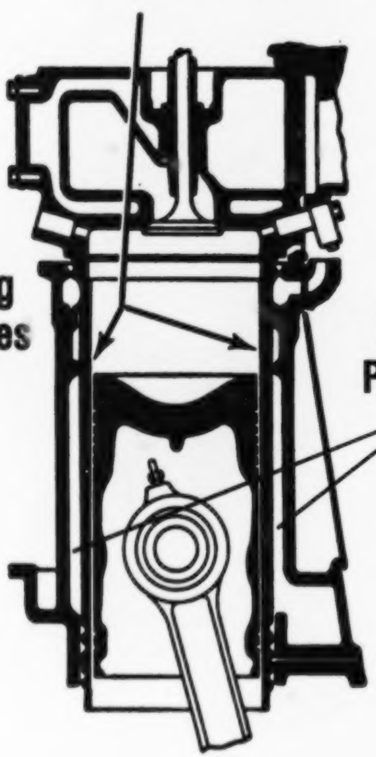
Cylinder Liners


Cooling
Passages

Cylinder Cast as One Piece
With no Cylinder Liner

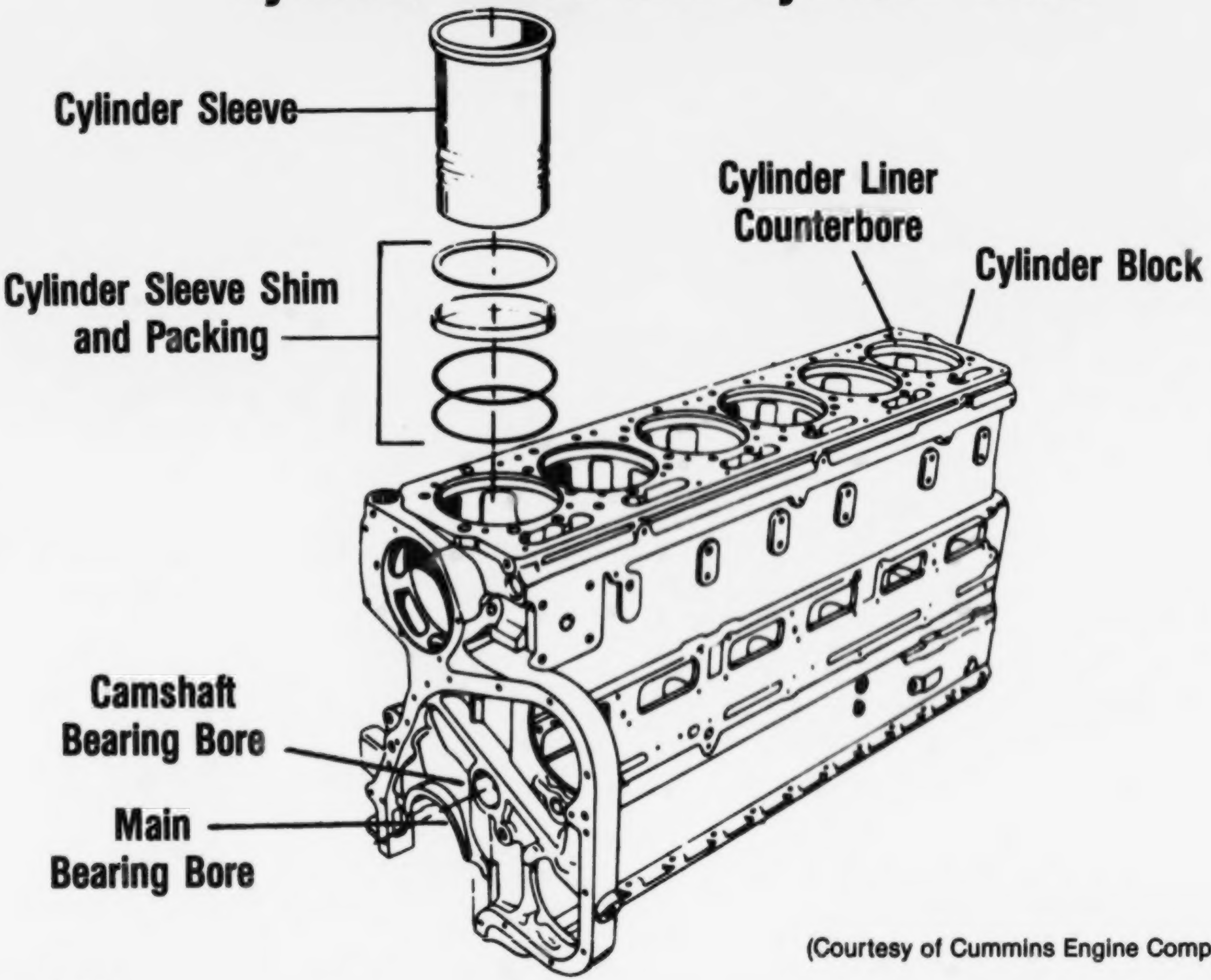

Liner is a Sleeve
Inside the Cylinder
Cooling
Passages

Dry Cylinder Liner
Coolant Does Not Come
in Contact with the Liner


Liner Forms
the Cylinder Itself
Cooling
Passages
Cooling
Passages

Wet Cylinder
Coolant Contacts Liner

Cylinder Block and Cylinder Liner


Cylinder Sleeve
Cylinder Liner Counterbore
Cylinder Block
Cylinder Sleeve Shim and Packing
Camshaft Bearing Bore
Main Bearing Bore

(Courtesy of Cummins Engine Company, Inc.)

CYLINDER BLOCKS AND LINERS
UNIT V-B

JOB SHEET #1 — REMOVE A CYLINDER LINER

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Cleaning solvent
6. Engine
7. Screw-type liner pulling tool
8. Hydraulic liner pulling tool
9. Emery cloth

B. Procedure

(CAUTION: Follow all shop safety procedures.)

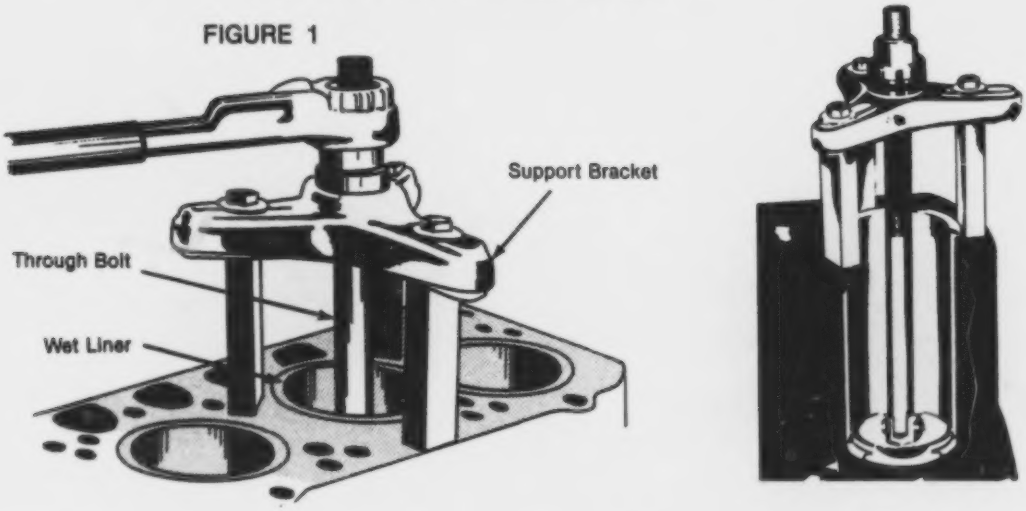
(NOTE: Check appropriate service manual for correct procedure for your particular engine.)

1. Remove a wet cylinder liner with screw-type puller.
   a. Examine the cylinder liner and obtain the proper size adapter plate.
   b. Note the identification mark on liner and block for future reference.

JOB SHEET #1

c. Use screw-type liner pulling tool. (Figure 1)

FIGURE 1



d. Fasten the adapter plate to the bottom of through bolt.

(NOTE: Make certain adapter plate is not bigger than outside diameter of the cylinder liner and does not touch the cylinder block bore.)

e. Screw the through bolt nut downward until it reaches the support bracket, holding the through bolt and adapter plate in place.

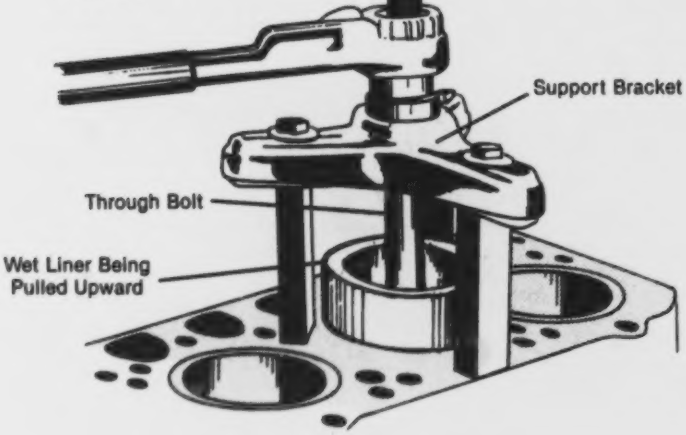
f. Check adapter plate to see that it is not touching the cylinder block.

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #1

g. Continue turning the nut, pulling the wet type liner from the block. Stop when the packing rings on the liner are above the block. (Figure 2)

FIGURE 2


Support Bracket
Through Bolt
Wet Liner Being Pulled Upward

h. Remove liner puller and adapter plate from the cylinder.

i. Remove the cylinder liner from the block bore by hand.

Obtain instructor's initials here ____________ before proceeding to next step.

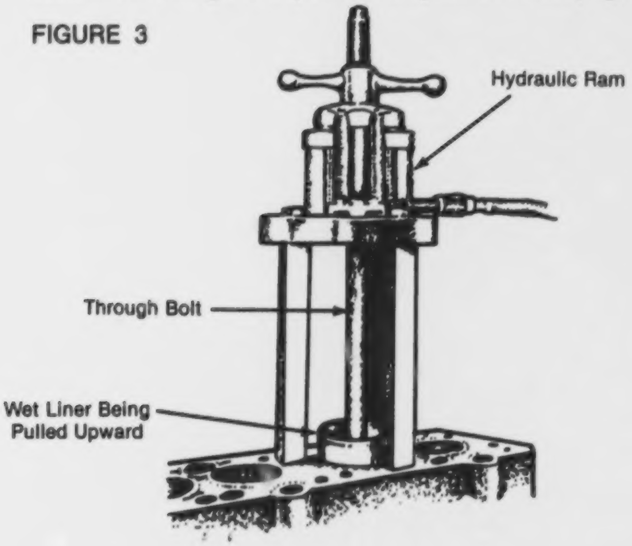
j. Remove the remaining cylinder liners from the block as outlined above.

2. Remove a dry cylinder with a hydraulic liner puller.

   a. Examine the cylinder liner and obtain the proper size adapter plate.

   b. Assemble through bolt plate and hydraulic ram. (Figure 3)

FIGURE 3


Hydraulic Ram
Through Bolt
Wet Liner Being Pulled Upward

JOB SHEET #1

c. Use the hydraulic hand pump to pull the cylinder liner from the cylinder bore.

d. Continue using the hydraulic pump until the cylinder liner can be removed by hand.

e. Remove remaining cylinder liners from block as outlined above.

Obtain instructor's initials here ____________.

CYLINDER BLOCKS AND LINERS
UNIT V-B

JOB SHEET #2 — CLEAN AND INSPECT A CYLINDER LINER

A. Tools and materials

1. Safety glasses
2. Shop towels (lint-free)
3. Basic hand tools
4. Appropriate service manual
5. Inside micrometer (bore gauge)
6. Outside micrometer
7. Dial indicator
8. Telescoping gauges
9. Cleaning solvent
10. Worksheets #1 and #2

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Check with the appropriate service manual before inspecting any cylinder liner for specification.)

1. Clean cylinder liner.

    a. Wash liner in a recommended cleaning solvent, and blow dry with compressed air.

    b. Wipe off the cylinder liner using a lint free shop towel.

    (NOTE: Use a hand wire brush to clean accumulated scale from the liner flange. On wet liners, also clean the packing ring grooves with a hand wire brush.)

    c. Visually inspect the cylinder liner for cracks, scoring or excessive corrosion and scale.

    Obtain instructor's initials here ____________ before proceeding to next step.

2. Measure cylinder liner flange.

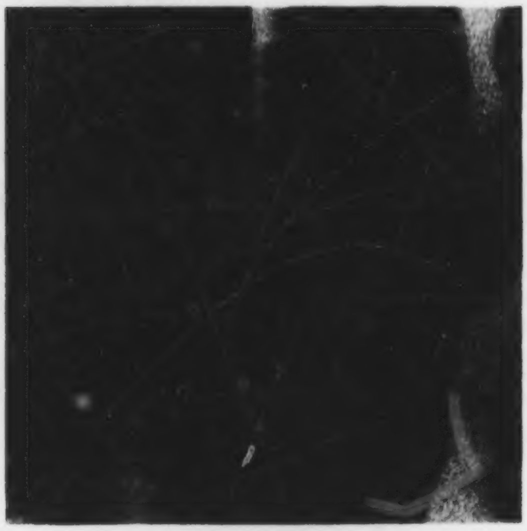
    a. Place the liner in a holding fixture or in an old cylinder block.

    (CAUTION: Under no circumstance should a vise of any kind be used.)

JOB SHEET #2

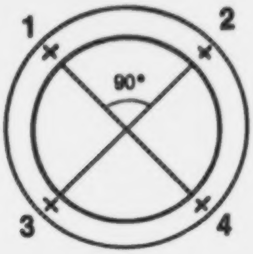
b. Measure the thickness of each cylinder liner flange with a micrometer. (Figure 1)

FIGURE 1



c. Measure the liner flange at four different points of the liner 90° apart from each other. (Figure 2)

FIGURE 2



Points of Measurement in a Cylinder Liner Flange

d. Record the measurements in the appropriate blanks on Worksheet #1.

e. Subtract the smallest measurement of the four measurements from the largest measurement to get the overall difference. Record overall difference on Worksheet #1.

JOB SHEET #2

f. Check appropriate service manual for overall difference of cylinder flange allowed.

g. Record the condition of the liner flange on Worksheet #1.

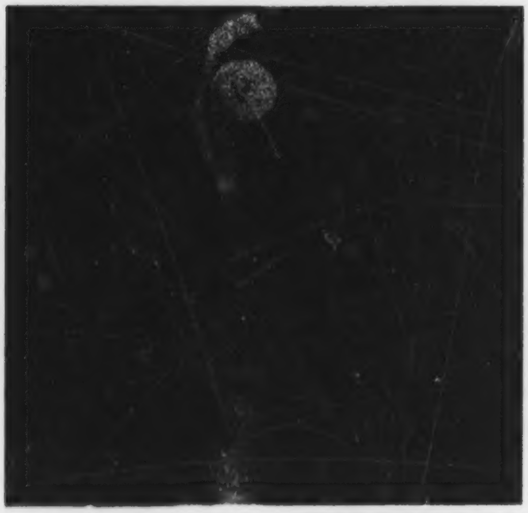
Obtain instructor's initials here ____________ before proceeding to next step.

3. Measure cylinder liner bore.

   a. Check appropriate service manual for specification of the cylinder liner bore.

   b. Measure cylinder liner with a cylinder bore gauge. (Figure 3)

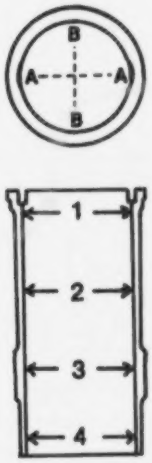
FIGURE 3



   c. Measure the length of the liner in at least four different points. Measure each point at two places 90° apart from each other. (Figure 4)

JOB SHEET #2

FIGURE 4



Points of Measurement
in a Cylinder Liner Bore

(NOTE: Check service manual since most manufacturers require measuring the liner at more than four points.)

d. Record the measurements in the appropriate blanks on Worksheet #2.

e. Measure liner at points 1-a; record measurement. Then move 90° from first measurement and measure at points 1-b; record the measurement.

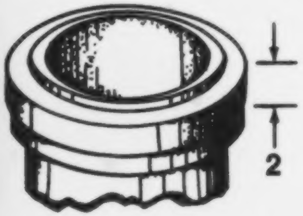
f. Subtract the smallest measurement from the largest to calculate out-of-roundness at point 1. Record this on Worksheet #2.

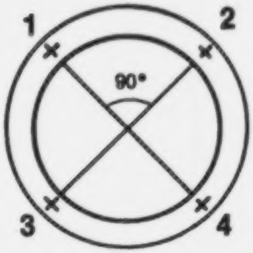
g. Repeat steps e and f for points 2a and 2b, 3a and 3b, 4a and 4b, and record the measurements in the appropriate blanks of Worksheet #2.

h. Subtract the smaller measurement at point 3 from the larger measurement of point 1 to calculate cylinder liner taper.

Obtain instructor's initials here ____________.

CYLINDER LINER FLANGE EVALUATION WORKSHEET #1





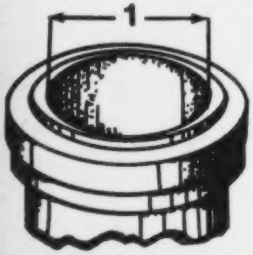
Cylinder Liner Specification

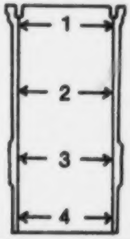
Flange Thickness ____________

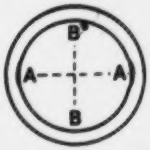
Permissible Flange Wear ____________

Cylinder Liner	Measurement at point 1	Measurement at point 2	Measurement at point 3	Measurement at point 4	Overall Difference	Condition	
						Good	Bad
1							
2							
3							
4							
5							
6							
7							
8							

CYLINDER LINER BORE EVALUATION WORKSHEET #2







Cylinder Bore Specification

Bore Diameter ____________________

Allowable Bore Taper ____________________

Allowable Bore Out-of-roundness ________

Cylinder Measurement	1	2	3	4	5	6	7	8
1-a								
1-b								
Out-of-roundness								
2-a								
2-b								
Out-of-roundness								
3-a								
3-b								
Out-of-roundness								
3-a								
3-b								
Out-of-roundness								
4-a								
4-b								
Out-of-roundness								
Taper								

CYLINDER BLOCKS AND LINERS
UNIT V-B

JOB SHEET #3 — CLEAN AND INSPECT A CYLINDER BLOCK

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Telescoping gauges
6. Outside micrometer
7. Depth micrometer
8. Inside micrometer (bore gauge)
9. Dial indicator
10. Worksheets #1, #2, and #3

B. Procedures

(CAUTION: Follow all shop safety procedures.)

1. Visually inspect the block before cleaning.

   (NOTE: Check for obvious defects and cracks that indicate the cylinder block may be unfit for further use.)

2. Clean the block in a hot tank to thoroughly clean all oil and coolant passages.

   (CAUTION: Be sure main bearing caps are installed before putting block in hot tank. If the main caps are not on the block, the heat will distort the block.)

   (NOTE: If the shop doesn't have a hot tank, send the block to a shop that does. Satisfactory results can not be obtained by cleaning by hand.)

3. Remove block from hot tank; wash with soap and water. Dry with compressed air.

   (CAUTION: Be sure to wash and blow out all oil and water passages.)

JOB SHEET #3

4. Measure main bearing house.

   a. Remove the main bearing caps from the block. (Figure 1)

   FIGURE 1

Main Bearing Cap
Main Bearing Saddle

   b. Place main bearing caps on a clean shop towel on a work bench in the order they were removed from the engine.

   c. Clean the main bearing caps and main bearing saddles with compressed air and a lint-free shop towel.

   d. Reinstall the main bearing caps in the order they were removed.

   e. Clean main bearing bolts and lubricate threads.

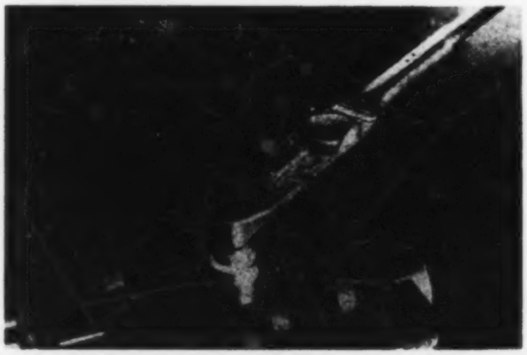
   (NOTE: Check with service manual; some manufacturers do not recommend lubricating bolt threads.)

   f. Install main bearing bolts and snug the bolts to the main bearing caps.

   g. Torque the main bearing bolts to specification. (Figure 2)

   (NOTE: Check service manual for torque sequence and amount of torque.)

   FIGURE 2

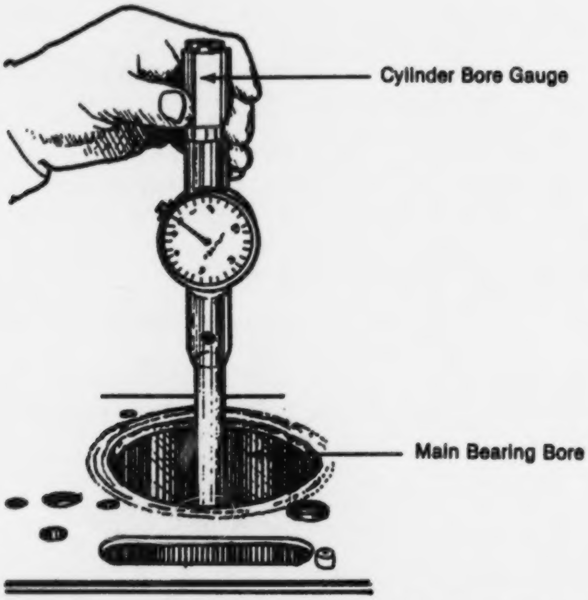


JOB SHEET #3

h. Check service manual for main bearing bore specification, and record specification on Worksheet #1.

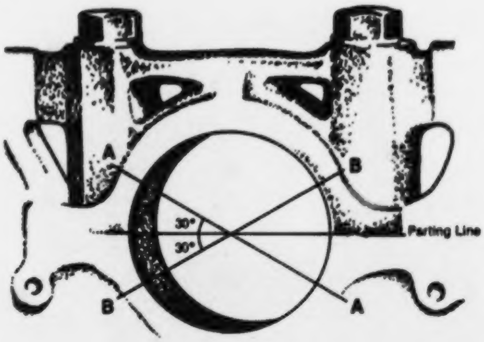
i. Measure main bearing bore with a cylinder bore gauge. (Figure 3)

FIGURE 3


Cylinder Bore Gauge
Main Bearing Bore

j. Measure the main boring at two locations: 30° above and below the parting line (point A and point B). (Figure 4)

FIGURE 4


A
B
30°
30°
Parting Line
B
A

k. Measure main bore at point A, and record measurement in the appropriate blank on Worksheet #1.

l. Measure the bore at point B, and record measurement in the appropriate blank on Worksheet #1.

JOB SHEET #3

m. Subtract the smaller measurement from the larger to calculate out-of-roundness.

n. Record the out-of-roundness in the appropriate blank on Worksheet #1 and check whether the bore is within specification.

Obtain instructor's initials here ____________ before proceeding to next step.

o. Measure remaining main bearing bores as outlined above and record on Worksheet #1.

(NOTE: After these measurements, most manufacturers recommend that the bore be checked for alignment. It is best to send the block to the manufacturer or a machine shop for this procedure.)

5. Measure cylinder liner counterbore.

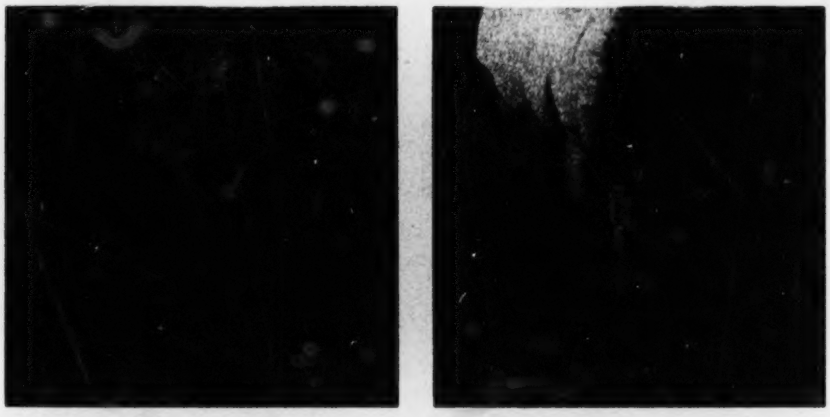
a. Check service manual for cylinder link counterbore specification and record on Worksheet #2.

b. Make sure that the liner counterbores are clean and free from scale before checking depth.

(NOTE: The block head deck has to be very clean to be able to measure counterbores.)

c. Measure the counterbore with either (a) dial indicator depth gauge, or (b) micrometer depth gauge. (Figure 5)

FIGURE 5



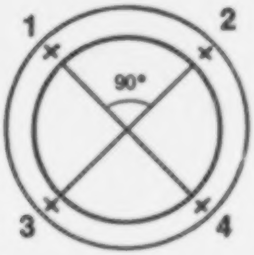
Measuring Cylinder Liner Counterbore with Dial Indicator Depth Gauge

Measuring Cylinder Liner Counterbore with Micrometer Depth Gauge

JOB SHEET #3

d. Measure the counterbore in at least four points 90° apart. (Figure 6)

FIGURE 6



Points of Measurement
of Cylinder Liner Counterbore

(NOTE: Some manufacturers require more measurement so check appropriate service manual.)

e. Measure at point 1 and record measurement in the appropriate blank on Worksheet #2.

f. Measure at points 2, 3, and 4 and record measurements in appropriate blanks on Worksheet #2.

g. Subtract the smaller measurement from the larger to calculate the difference in wear.

Obtain instructor's initials here ____________ before proceeding to next step.

h. Measure remaining counterbores, and record measurements in the appropriate blanks on Worksheet #2.

6. Measure camshaft bearing bores.

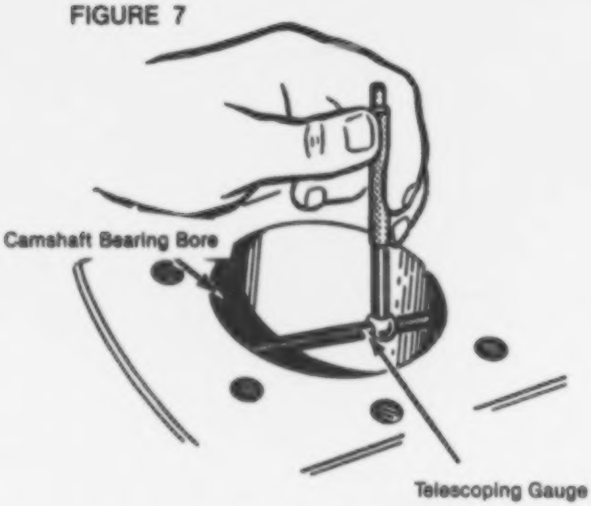
(NOTE: It is a common practice to replace the camshaft bearing when a major overhaul is made. The camshaft bores are rarely distorted, worn, or damaged but need to be checked.)

a. Check service manual for camshaft bearing bore specification and record on Worksheet #3.

b. Measure the bores with an inside micrometer or with a telescoping gauge. (Figure 7)

JOB SHEET #3

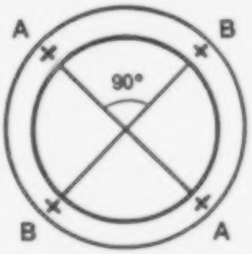
FIGURE 7



c. Measure the legs of the telescoping gauge with an outside micrometer, and record the measurement on Worksheet #3.

d. Measure each camshaft bore at two locations 90° apart from each other. (Figure 8)

FIGURE 8



Points of Measurement
of Camshaft Bearing Bore

e. Measure camshaft bore at point A, and record the measurement in the appropriate blank on Worksheet #3.

f. Measure camshaft bore at point B, and record the measurement in the appropriate blank on Worksheet #3.

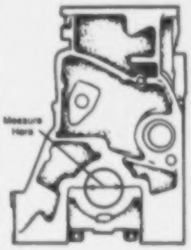
g. Subtract the smaller measurement from the larger to calculate out-of-roundness; record in the appropriate blank.

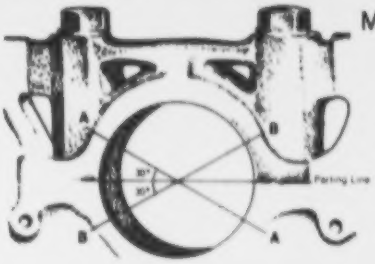
Obtain instructor's initials here ____________ before proceeding to next step.

h. Measure remaining camshaft bearing bores, and record the measurements in the appropriate blanks on Worksheet #3.

JOB SHEET #3

CYLINDER BLOCK EVALUATION WORKSHEET #1


Measure Here


A
B
30°
30°
Parting Line
B
A

Main Bearing Bore Specification

Cylinder Bore Diameter ____________

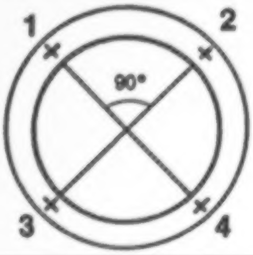
Permissible Bore Out-of-Roundness ____________

Cylinder Bearing Bore	Point A Measurement	Point B Measurement	Out-of Roundness	Bore Within Specification		Comments
				Yes	No	
1						
2						
3						
4						
5						
6						
7						

Instructor's Initials ____________

JOB SHEET #3

CYLINDER BLOCK EVALUATION WORKSHEET #2



Specification

Counterbore Depth _____

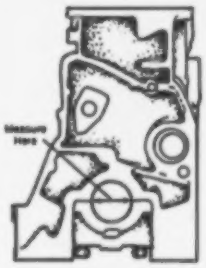
Permissible Wear _____

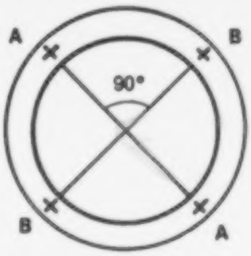
Cylinder Counter Bore	1	2	3	4	5	6	7	8
Measurement at point 1								
Measurement at point 2								
Measurement at point 3								
Measurement at point 4								
Wear								

Instructor's Initial ____________

JOB SHEET #3

CYLINDER BLOCK EVALUATION WORKSHEET #3





Specification

Camshaft Bearing Bore ____________

Permissible Out-of-Roundness ____________

Camshaft Bearing Bore	1	2	3	4	5	6
Measurement at point A						
Measurement at point B						
Out-of-roundness						

Instructor's Initial ____________

CYLINDER BLOCKS AND LINERS
UNIT V-B

JOB SHEET #4 — INSTALL CYLINDER LINER INTO CYLINDER BLOCK AND CHECK LINER PROTRUSION

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Clean lubricating oil
6. Cylinder liner installation tool
7. Dial indicator and gauge block

B. Procedure

(CAUTION: Follow all shop safety precautions.)

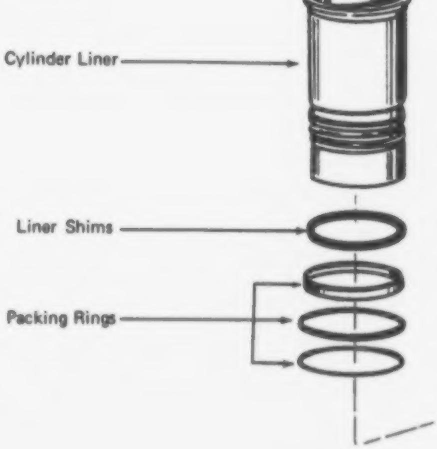
1. Install a wet liner into the cylinder block

    a. Clean all machined mating surfaces of the cylinder liner and the cylinder block.

    (NOTE: Any dirt or scale on these surfaces can cause distortion of the liner and even engine failure.)

    b. Make certain that the necessary shims (if used) are installed with each liner in order to ensure liner protrusion. (Figure 1)

FIGURE 1



JOB SHEET #4

c. Make sure the ring grooves are clean at the bottom of the liner.

(NOTE: Some engines may have ring grooves at the bottom of the cylinder bore instead of the liner.)

d. Roll the packing rings carefully over the liner and into their grooves to avoid stretching the rings. (Figure 2)

FIGURE 2

e. Use clean oil to lubricate the packing rings and machined portion of the block on which the rings seat. (Figure 3)

(NOTE: Check service manual for correct lubricant.)

FIGURE 3

JOB SHEET #4

f. Install proper thickness of shims (if used) on the cylinder liner.

g. Install the liner into the cylinder block bore with a quick push by hand. (Figure 4)

FIGURE 4

h. Use an installation tool to push the flange of the cylinder liner against the counterbore ledge. (Figure 5)

FIGURE 5

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #4

i. Recheck cylinder liner bore diameter with a cylinder bore gauge to see if the liner is distorted.

j. Check cylinder liner protrusion as outlined in Step 3 of this job sheet.

2. Install a dry liner into the cylinder block.

a. Clean the cylinder block bore and counterbore.

(NOTE: Some manufacturers require honing the cylinder block bore. Check appropriate service manual.)

b. Install proper thickness of shims (if used) onto the cylinder liner.

c. Inspect the cylinder liner in the cylinder bore; the liner should enter bore freely half of its length.

(NOTE: If liner does not enter freely for at least half of its length, the cylinder bore may have to be rehoned. Check service manual for proper method.)

d. Install liner with installation tool until liner is one-half inch above the block deck.

e. Blow out the counterbore with compressed air to remove any foreign material that may have accumulated. (Figure 6)

FIGURE 6

f. Finish driving liner into block until liner flange is seated into counterbore.

Obtain instructor's initials here ____________ before proceeding to next step.

g. Recheck cylinder bore diameter with a cylinder bore gauge to see if the liner is distorted.

h. Check cylinder liner protrusion as outlined in Step 3 of this job sheet.

652

JOB SHEET #4

3. Measure cylinder liner protrusion.

   a. Check service manual for cylinder liner protrusion specification and record on Worksheet #1.

   b. Install liner hold down clamps, and check liner protrusion with a dial indicator and gauge block or a micrometer depth gauge. (Figure 7)

FIGURE 7

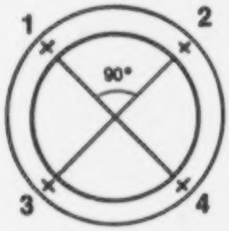
Measuring Cylinder Liner Protrusion with Dial Indicator

Measuring Cylinder Liner Protrusion with Micrometer Depth Gauge

(NOTE: If liner protrusion is not within specification, shims can be placed under the flange of cylinder liner to bring the liner protrusion within specification.)

   c. Measure the liner protrusion at four equal points around the liner. (Figure 8)

FIGURE 8



Points of Measurement of Cylinder Liner Protrusion

JOB SHEET #4

d. Measure liner protrusion at point 1, and record the measurement in the appropriate blank on Worksheet #1.

e. Measure liner protrusion at points 2, 3, and 4, and record measurements in the appropriate blanks on Worksheet #1.

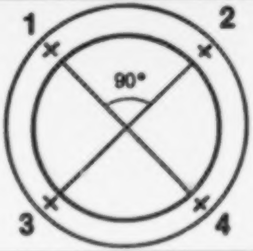
f. Subtract the smallest measurement from the largest to calculate the difference in height and record on Worksheet #1.

Obtain instructor's initials here ____________ before proceeding to next step.

g. Measure remaining liner protrusion and record in the appropriate blanks on Worksheet #1.

JOB SHEET #4

CYLINDER BLOCK EVALUATION WORKSHEET #1



Specification

Liner Protrusion ________

Cylinder Liner	Point 1	Point 2	Point 3	Point 4	Difference in Height	Comments
1						
2						
3						
4						
5						
6						
7						
8						

Instructor's Initial ____________

CYLINDER BLOCKS AND LINERS
UNIT V-B

PRACTICAL TEST
JOB SHEET #1 — REMOVE A CYLINDER LINER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Used shop safety precautions.	______	______
3.	Selected correct adapter plate for wet liner.	______	______
4.	Used screw puller.	______	______
5.	Removed liner puller from the cylinder liner.	______	______
6.	Removed the wet liner by hand.	______	______
7.	Removed remaining wet liners.	______	______
8.	Selected correct adapter plate for dry liners.	______	______
9.	Used hydraulic liner puller.	______	______
10.	Pulled liner up enough to remove by hand.	______	______
11.	Removed remaining dry liner.	______	______
12.	Checked in/put away tools and materials.	______	______
13.	Cleaned the work area.	______	______
14.	Used proper tools correctly.	______	______
15.	Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
16.	Practiced safety rules throughout procedure.	______	______
17.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Wet cylinder liner is removed correctly.				
	4	3	2	1
Dry cylinder liner is removed correctly.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER BLOCKS AND LINERS
UNIT V-B

PRACTICAL TEST
JOB SHEET #2 — CLEAN AND INSPECT A CYLINDER LINER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned the cylinder liners.	______	______
4. Inspected liner visually for damage.	______	______
5. Measured liner flange.	______	______
6. Recorded liner flange measurements on Worksheet #1.	______	______
7. Filled out Worksheet #1.	______	______
8. Measured cylinder liner bore for taper.	______	______
9. Measured cylinder liner bore for out-of-roundness.	______	______
10. Recorded bore measurements on Worksheet #2.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Cylinder liner is cleaned properly.	4	3	2	1
Cylinder liner flange is within specification.	4	3	2	1
Cylinder liner bore taper is within specification.	4	3	2	1
Cylinder liner bore out-of-roundness is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER BLOCKS AND LINERS
UNIT V-B

PRACTICAL TEST
JOB SHEET #3 — CLEAN AND INSPECT A CYLINDER BLOCK

STUDENT'S NAME ________________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Visually inspected block for damage.	______	______
4. Cleaned block for inspection.	______	______
5. Measured block main bearing bores.	______	______
6. Recorded main bearing bore measurements.	______	______
7. Measured cylinder liner counterbores.	______	______
8. Recorded counterbore measurements.	______	______
9. Measured camshaft bearing bores.	______	______
10. Recorded camshaft bearing bore measurements.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Cylinder block is cleaned properly for inspection.	4	3	2	1
Main bearing bores are within specification.	4	3	2	1
Cylinder liner counterbores are within specification.	4	3	2	1
Camshaft bearing bores are within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER BLOCKS AND LINERS
UNIT V-B

PRACTICAL TEST
JOB SHEET #4 — INSTALL CYLINDER LINER INTO CYLINDER BLOCK AND CHECK LINER PROTRUSION

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed wet liner into block.	______	______
4. Cleaned block and liner before installation.	______	______
5. Installed liner shims.	______	______
6. Cleaned packing ring grooves.	______	______
7. Installed packing into liner grooves.	______	______
8. Lubricated packing rings.	______	______
9. Installed liner into cylinder bore.	______	______
10. Installed dry liner into block.	______	______
11. Checked liner protrusion.	______	______
12. Recorded protrusion measurement onto worksheet.	______	______
13. Checked in/put away tools and materials.	______	______
14. Cleaned the work area.	______	______
15. Used proper tools correctly.	______	______
16. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
17. Practiced safety rules throughout procedure.	______	______
18. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Wet liner is installed correctly.	4	3	2	1
Dry liner is installed correctly.	4	3	2	1
Liner protrusion is within specification.	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CYLINDER BLOCKS AND LINERS
UNIT V-B

NAME ____________________ SCORE ____________________

TEST

1. Match the terms related to cylinder block with the correct definitions.

_____a. Cylinder and water jacket cast into the block; does not use cylinder liners

_____b. Sleeve inserted into the bores of the engine block to form the cylinder walls

_____c. Stationary part that gives the engine form and shape, and furnishes a foundation for moving parts

_____d. Cylinder sleeve inserted into a block bore to form part of the water jacket

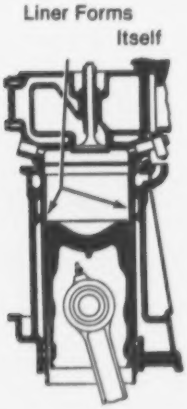
_____e. Cylinder sleeve inserted into a block bore that makes no contact with the coolant system

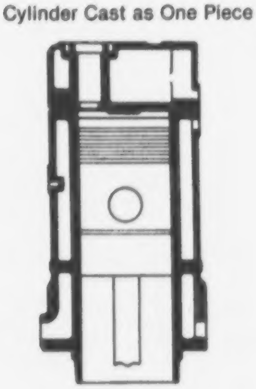
_____f. Lip cut in top of block into which the cylinder sleeve is fitted

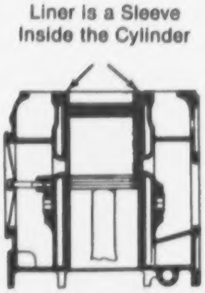
_____g. Distance the liner stands out or protrudes above the block top deck surface after installation

1. Block
2. Counterbore
3. Cylinder liner
4. Dry liner
5. Integral cylinder
6. Protrusion
7. Wet liner

2. Identify the types of cylinder block construction.







a. ____________ b. ____________ c. ____________

TEST

3. Name two advantages a removable liner has over an integral cylinder bore.

   a. ____________________

   b. ____________________

4. Match the types of liners with statements on wet and dry liners.

_____a.	Less expensive	1. Wet liners
_____b.	Provide better cooling of cylinder	2. Dry liners
_____c.	May be replaced separately when worn	
_____d.	Allow room for expansion lengthwise	

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

5. Demonstrate the ability to:

   a. Remove a cylinder liner. (Job Sheet #1)

   b. Clean and inspect a cylinder liner. (Job Sheet #2)

   c. Clean and inspect a cylinder block. (Job Sheet #3)

   d. Install cylinder liner into cylinder block and check liner protrusion. (Job Sheet #4)

CYLINDER BLOCKS AND LINERS
UNIT V-B

ANSWERS TO TEST

1. a. 5
   b. 3
   c. 1
   d. 7
   e. 4
   f. 2
   g. 6

2. a. Wet liner
   b. Integral
   c. Dry liner

3. a. Allows room for expansion lengthwise
   b. May be replaced separately when worn

4. a. 2
   b. 1
   c. 1 and 2
   d. 2

5. Performance skills evaluated to the satisfaction of the instructor

CRANKSHAFT AND BEARINGS
UNIT VI-B

UNIT OBJECTIVE

After completion of this unit, the student should be able to name the parts of a crankshaft and list engine indications of bearing failure. The student should also be able to remove, inspect, and replace a crankshaft and bearings. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to crankshafts and bearings with the correct definitions.
2. Identify parts of a crankshaft.
3. Match the arrangement of crankcase throws with the number of cylinders in the engine.
4. Arrange in order steps in determining corresponding cylinders of a four-cycle engine.
5. Identify ways crankshaft balance is maintained.
6. Select true statements concerning the lubrication of the crankshaft and surrounding parts.
7. Distinguish between a bushing and a bearing.
8. Name three materials used in making bearing linings.
9. Identify types of bearing locks.

OBJECTIVE SHEET

10. Define bearing crush.

11. State the purpose of oil grooves in the bearing.

12. Identify types of thrust bearings.

13. List three engine indications of bearing failure.

14. Match the percentages of bearing failure with the causes of bearing failure.

15. Select true statements concerning the functions of the flywheel.

16. Identify types of vibration dampers.

17. Determine piston location, stroke position, and valve adjustment of a four-cycle four cylinder engine. (Assignment Sheet #1)

18. Determine piston location, stroke position, and valve adjustment of a four-cycle six cylinder engine. (Assignment Sheet #2)

19. Determine piston location, stroke piston, and valve adjustment of a four-cycle eight cylinder engine. (Assignment Sheet #3)

20. Demonstrate the ability to:

    a. Remove a crankshaft. (Job Sheet #1)

    b. Inspect and measure a crankshaft and bearings. (Job Sheet #2)

    c. Install bearings and crankshaft. (Job Sheet #3)

CRANKSHAFT AND BEARINGS
UNIT VI-B

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets and handouts.

F. Discuss information and assignment sheets and handouts.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

    1. Display different types of thrust bearings.
    2. Show students different engine crankshaft designs.
    3. Have students make a list of specifications from a service manual. (Handout #1).
    4. Have students make a list of the number of engines that use a rubber element type vibration damper and how many use a viscous type.
    5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Engine Company Shop Manual.* Columbus, IN: Cummins Engine Company, Inc., 1984.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

C. *Engine Service Manual.* Peoria, IL: Caterpillar Tractor Company, 1982.

D. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Filmstrips

1. *Crankshafts, Balancers, Dampers and Bearings* (52 slides and script)
   Caterpillar Tractor Co.
   Literature Orders Section
   1335 S.W. Washington
   Peoria, IL 61602

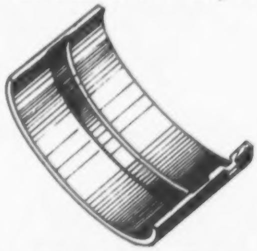
2. *Mack 6 Cylinder Engine Rebuild — Part 1 and 2*
   Mack Trucks, Inc.
   Educational Communications Inc.
   Department M
   761 Fifth Avenue
   King of Prussia, PA 19406

CRANKSHAFTS AND BEARINGS
UNIT VI-B

INFORMATION SHEET

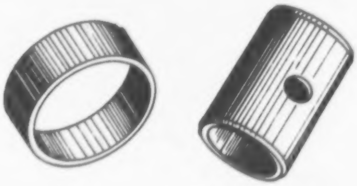
I. **Terms and definitions** (Transparency 1)

A. Bearing — Half round sleeve normally used to support heavy loads



B. Bearing clearance — Measured difference between the inside diameter of the bearing and the outside diameter of the journal

C. Bushing — Full round sleeve normally used to support light loads



D. Corresponding cylinders — Two pistons in a four-cycle engine moving in the same direction but on different strokes

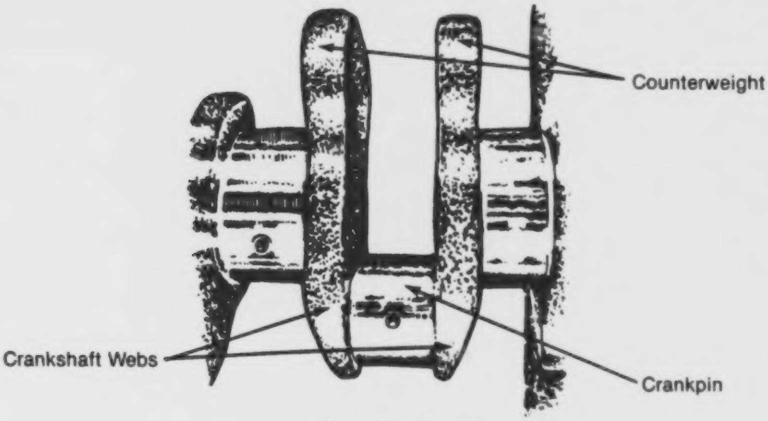
(NOTE: A two-cycle engine does not have corresponding cylinders.)

E. Crankpin — Outer end of crank throw

(NOTE: The crankpin is also called a connecting rod journal.)

INFORMATION SHEET

F. Crankshaft throw — Two crankshaft webs and one crankpin


Counterweight
Crankshaft Webs
Crankpin

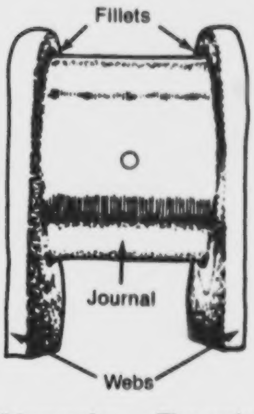
Crankshaft Throw

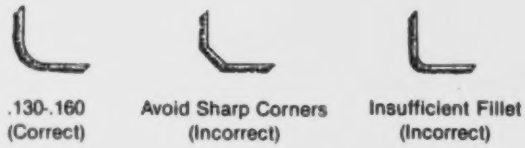
G. Crankshaft web — Forms the crank or throw between the crankpin and main journal

H. Counterweights — Weights mounted on the crankshaft that reduce the vibration and bearing loads due to internal force

I. Dynamically balanced — Balanced against the rotary outward force at high speed

J. Fillet — A curved joint between the journal and the web to add strength


Fillets
Journal
Webs


.130-.160
(Correct)
Avoid Sharp Corners
(Incorrect)
Insufficient Fillet
(Incorrect)

Correct and Incorrect Fillet Angles

K. Firing order — The order in which the cylinders deliver their power strokes

Example: Six cylinder engine with a firing order of 1-5-3-6-2-4.

L. Integral crankshaft — Made from a single billet of steel

INFORMATION SHEET

M. Journal — The part of a shaft or axle in contact with the bearing

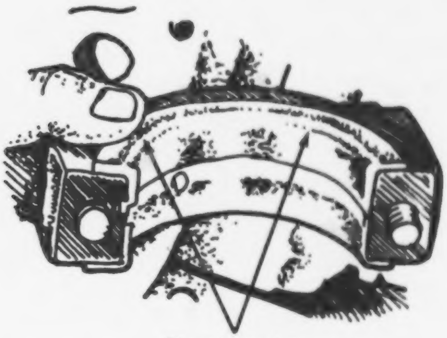
N. Short block — Engine block without cylinder head and external accessories

O. Statically balanced — Balanced while at rest

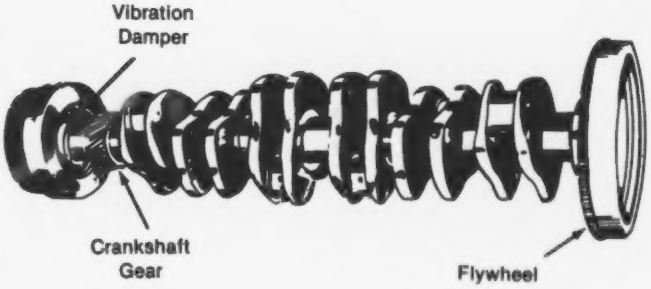
P. Thrust bearing (not always end bearing) — Controls crankshaft end play

Example: Flanged main bearing used to control crankshaft end play

(NOTE: The thrust bearing affects end clearance.)


Thrust Bearing
With Flange
(extra lip)

Q. Vibration damper (harmonic) — Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine


Vibration Damper
Crankshaft Gear
Flywheel

INFORMATION SHEET

II. **Parts of a crankshaft**

A. Main bearing journals

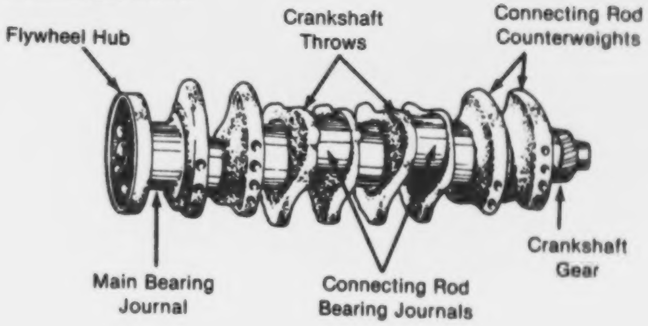
B. Connecting rod bearing journals

C. Connecting rod counterweights

D. Flywheel hub or flange

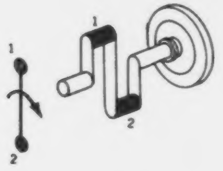
E. Crankshaft gear

F. Crankshaft throw

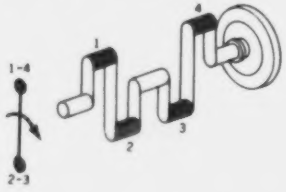

Flywheel Hub
Crankshaft Throws
Connecting Rod Counterweights
Main Bearing Journal
Connecting Rod Bearing Journals
Crankshaft Gear

III. **Arrangement of crankshaft throws** (Transparency 2)

A. Two and four cylinder engine crankshaft throws are 180° apart



Two Cylinder Engine



Four Cylinder Engine

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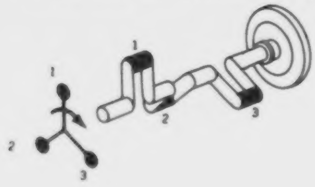
(NOTE: Two cylinder engine: #1 cylinder is at TDC; #2 cylinder is at BDC.)

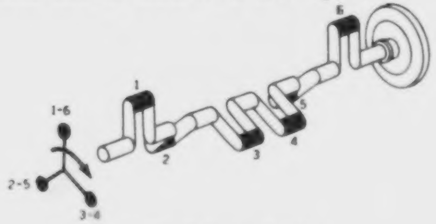
(NOTE: Four cylinder engine: corresponding cylinders #1 and #4 are at TDC; corresponding cylinders #2 and #3 are at BDC.)

INFORMATION SHEET

B. Three and six cylinder engine crankshaft throws are 120° apart



Three Cylinder Engine



Six Cylinder Engine

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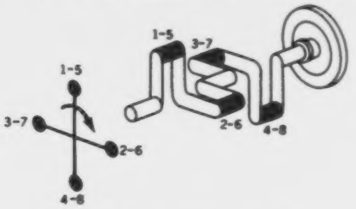
(NOTE: Three cylinder engine: only #1 cylinder is at TDC; #3 is at 120°ATDC; #2 is at 120° BTDC.)

(NOTE: Six cylinder engine: corresponding cylinders #1 and #6 are at TDC; #3 and #4 are at 120° ATDC; #2 and #5 are at 120° BTDC.)

C. Eight cylinder engine crankshaft throws are 90° apart



Eight Cylinder V-Type Engine

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(NOTE: Corresponding cylinders #1 and #5 are at TDC; #2 and #6 are at 90° ATDC; #3 and #7 are at 90° BTDC; #4 and #8 are at BDC.)

IV. **Steps in determining the corresponding cylinders of a four-cycle engine** (Assignment Sheets 1, 2, and 3)

A. Find the firing order of the engine.

(NOTE: Look in appropriate service manual for the firing order.)

B. Write the last half of the cylinder numbers of the firing order below the first half of the numbers.

Example: Assume the firing order is 1-5-3-6-2-4. Place the last three cylinder numbers below the first three cylinders, as follows:

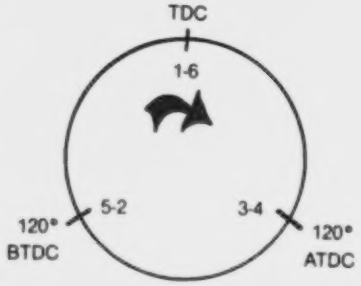
1-5-3
6-2-4

The corresponding cylinders are #1 and #6, #2 and #5, #3 and #4.

INFORMATION SHEET

C. Place the corresponding cylinders on a chart.

Example:



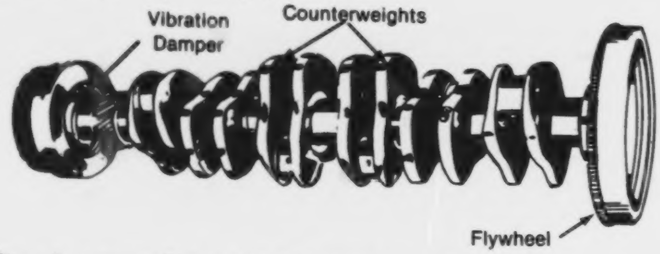
D. Locate #1 cylinder on compression stroke and its corresponding cylinder at top dead center as shown on chart.

V. **Maintaining crankshaft balance** (Transparency 3)

A. Counterweights

B. Vibration damper

C. Flywheel



VI. **Lubrication of crankshaft and surrounding parts** (Transparency 4)

A. Oil pressure through crankshaft lubricates rod and main bearing

B. Excess oil from rod and main bearing lubricates surrounding parts

VII. **Materials used in bearing linings**

A. Tin or lead base babbit

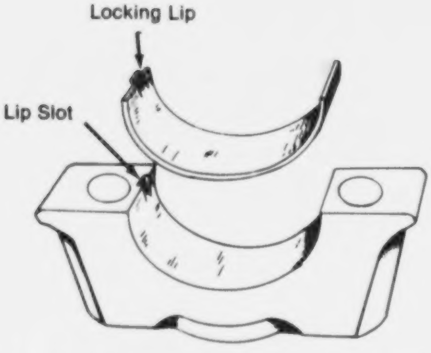
B. Copper or aluminum alloys

C. Multilayers of copper or aluminum alloys and silver combinations

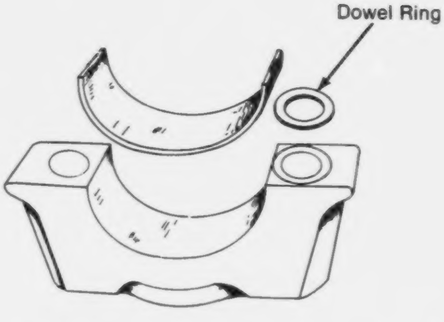
INFORMATION SHEET

VIII. **Types of bearing locks** (Transparency 5)

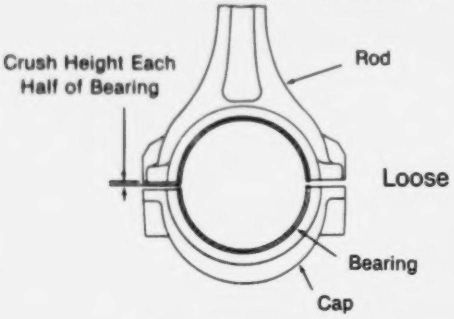
A. Lip slot

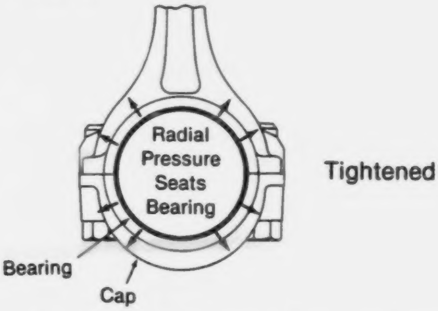

Locking Lip
Lip Slot

B. Dowel ring



IX. **Bearing crush** — Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened (Transparency 6)


Crush Height Each Half of Bearing
Rod
Loose
Bearing
Cap


Radial Pressure Seats Bearing
Tightened
Bearing
Cap

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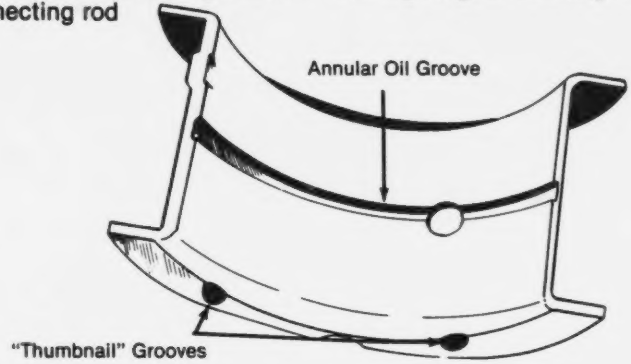
(CAUTION: When installing bearings into the rods or mains, do not put lubricant on the back side of bearing because this will affect the crush and bearing clearance.)

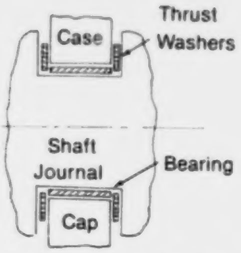
X. **Purpose of bearing oil grooves** — Bearing oil grooves carry the oil through to the connecting rod


Annular Oil Groove
"Thumbnail" Grooves

INFORMATION SHEET

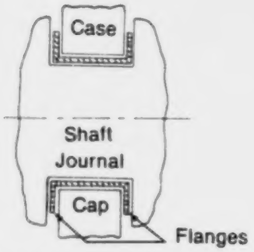
XI. Types of thrust bearings

A. Separate thrust washers



Separate Thrust Washers

B. Thrust flanges on bearings



Thrust Flanges on Bearings

XII. Engine indications of bearing failure

A. Drop in lubricating oil pressure

B. Excessive oil consumption

C. Engine noise — Rhythmic knock

XIII. Major causes of bearing failure (Transparency 7)

A. Dirt — 43 percent

B. Lack of lubrication — 16 percent

C. Improper assembly — 14 percent

D. Misalignment — 10 percent

E. Overloading — 9 percent

F. Other — 8 percent

XIV. Functions of flywheel

A. Stores energy for momentum between power strokes

B. Smooths out speed of crankshaft

C. Transmits power to driven machine

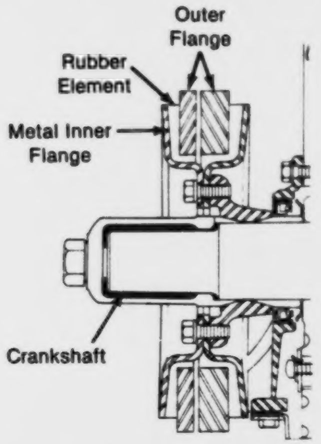
D. Provides a drive for starter via ring gear

E. Serves as a facing for engine clutch

INFORMATION SHEET

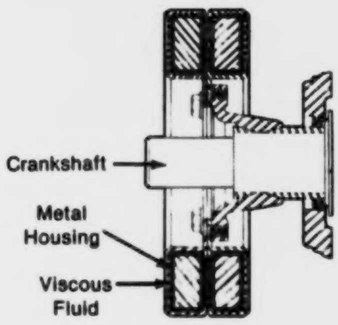
XV. Types of vibration dampers

A. Rubber-element damper — A two-piece housing of metal with a hard rubber element molded between it to absorb the vibration of the crankshaft.


Outer Flange
Rubber Element
Metal Inner Flange
Crankshaft

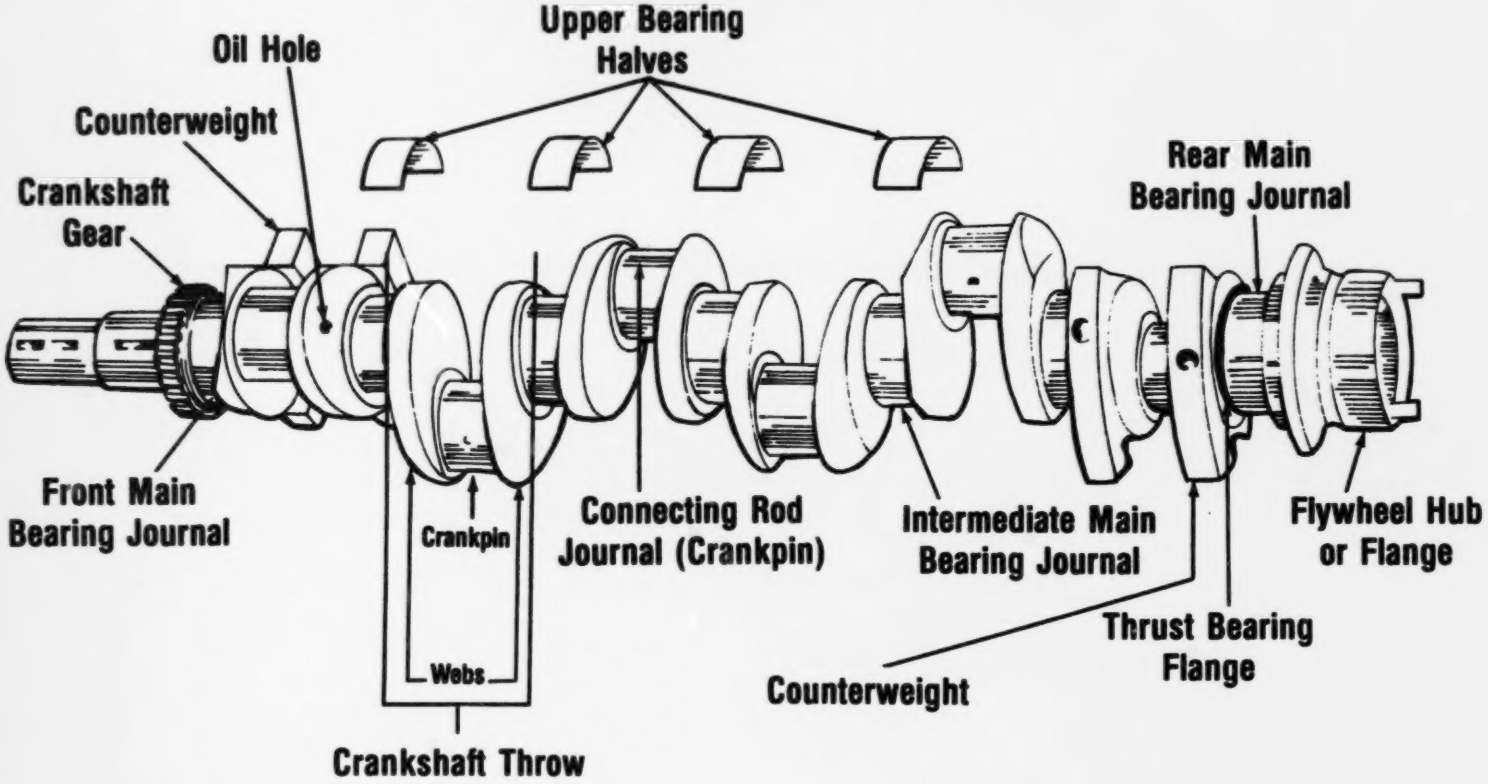
(Courtesy of Deutz-Allis Corporation.)

B. Viscous damper — A two-piece housing containing a special greaselike fluid that absorbs the vibration of the crankshaft.

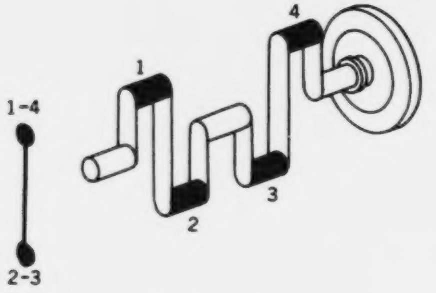

Crankshaft
Metal Housing
Viscous Fluid

(Courtesy of Deutz-Allis Corporation.)

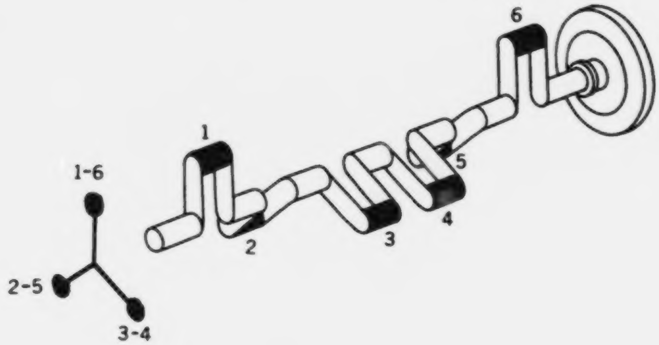
Parts of the
Typical Two-Cycle Crankshaft


Upper Bearing Halves
Oil Hole
Counterweight
Crankshaft Gear
Rear Main Bearing Journal
Front Main Bearing Journal
Crankpin
Webs
Crankshaft Throw
Connecting Rod Journal (Crankpin)
Intermediate Main Bearing Journal
Thrust Bearing Flange
Counterweight
Flywheel Hub or Flange

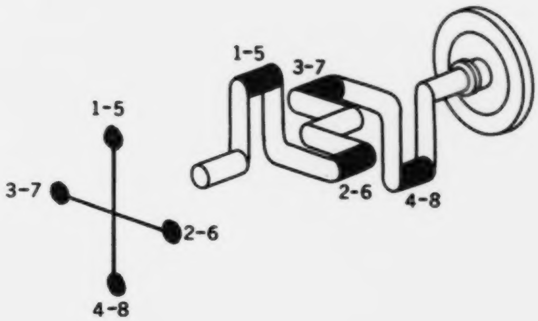
Arrangement of Crankshaft Throws



4–Cylinder Engine


6
1
1-6
5
2-5
2
3
4
3-4

6–Cylinder Engine


1-5
3-7
1-5
3-7
2-6
2-6
4-8
4-8

8–Cylinder V–Type Engine

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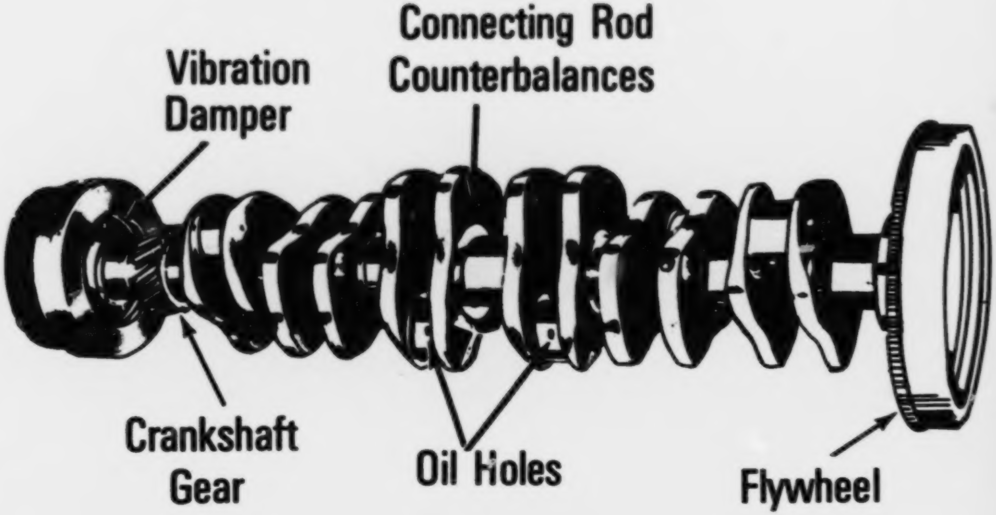
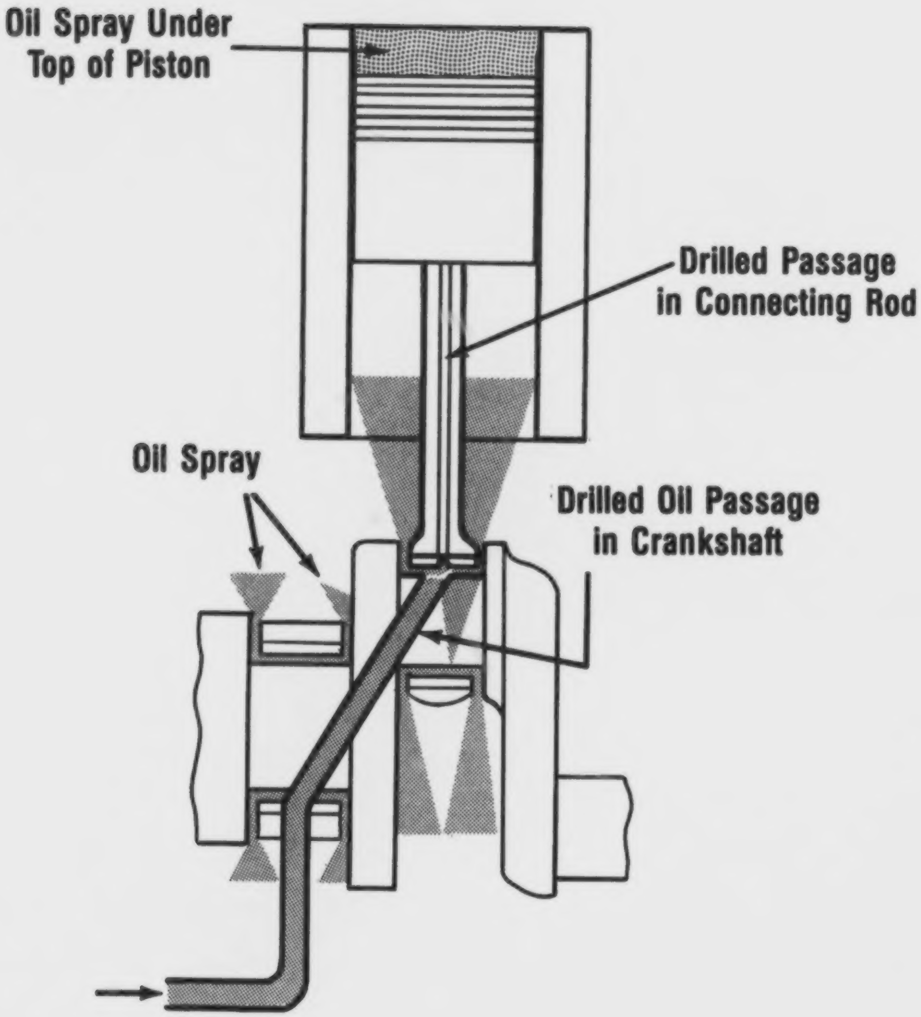
Counterweights, Vibration Damper and Flywheel

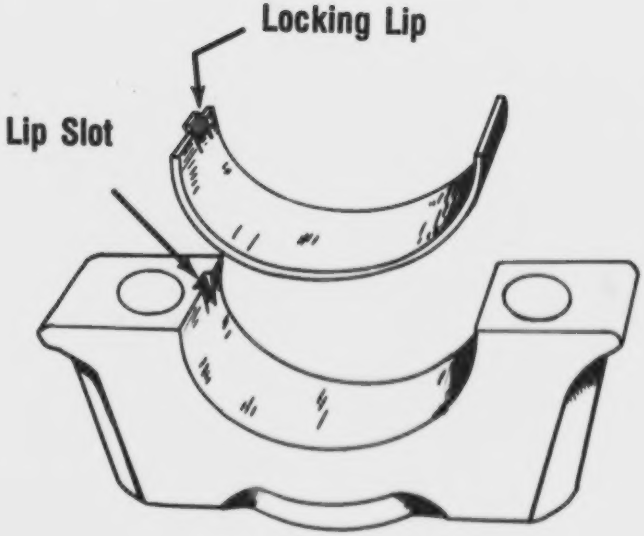

Connecting Rod
Counterbalances
Vibration
Damper
Crankshaft
Gear
Oil Holes
Flywheel

A Six–Cylinder, Seven–Main– Bearing Crankshaft.

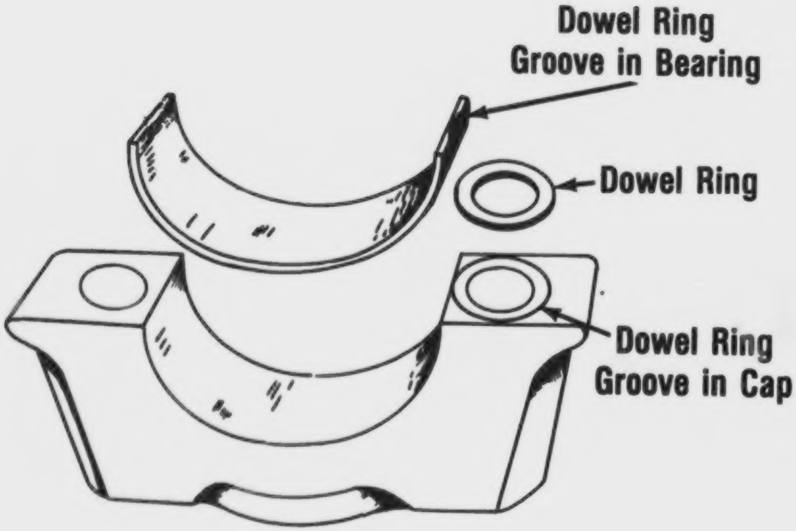
Crankshaft Lubrication


Oil Spray Under Top of Piston
Drilled Passage in Connecting Rod
Oil Spray
Drilled Oil Passage in Crankshaft

Bearing Locks

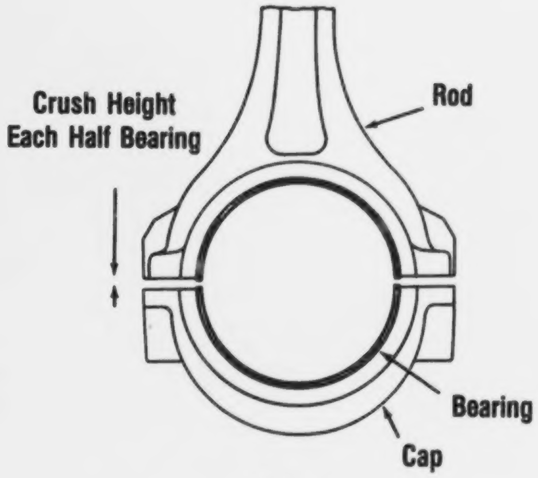

Locking Lip
Lip Slot

685

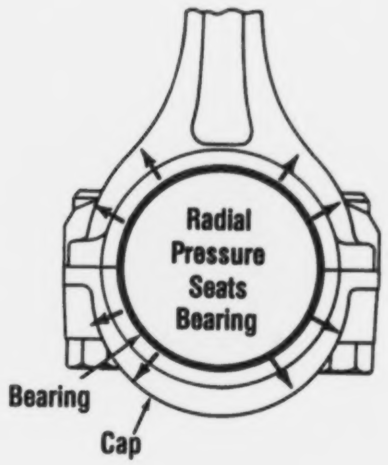

Dowel Ring
Groove in Bearing
Dowel Ring
Dowel Ring
Groove in Cap

686

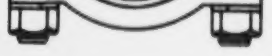
Bearing Crush


Crush Height
Each Half Bearing
Rod
Bearing
Cap

Loose

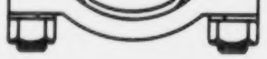

Radial
Pressure
Seats
Bearing
Bearing
Cap

Tightened



Lack of Crush

Edges of Bearing
Curl In Toward Shaft



Too Much Crush

Bearing Buckles
When Cap Tightened

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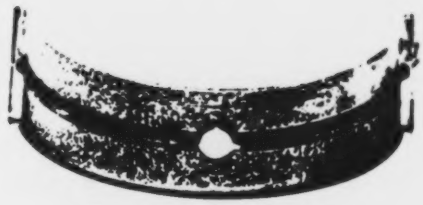
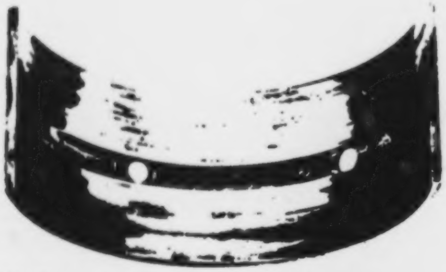
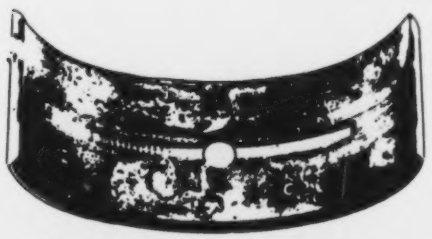
Causes of Bearing Failure



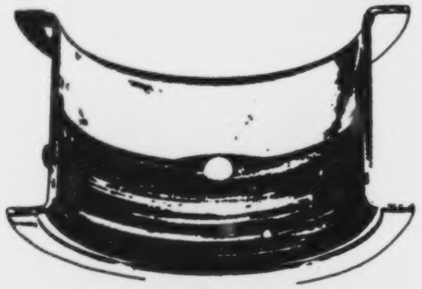
Damage From Dirt
Embedded In Bearing



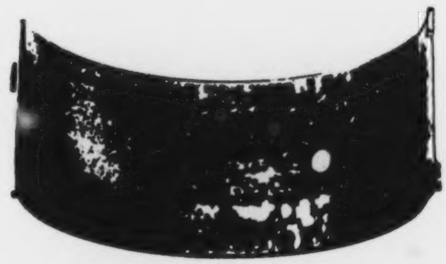
Oil Starvation Caused This Damage



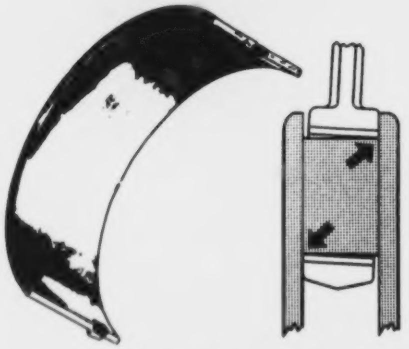
Bearing Fatigue Caused By
Overloading and Heat



Wear On One Edge of Bearing
Caused by Tapered Journals



Corrosion From Acid
Formation In Oil



Excessive Wear Caused
by a Bent Connecting Rod

CRANKSHAFT AND BEARINGS
UNIT VI
HANDOUT #1

ENGINE MAKE ____________________ **STUDENT NAME** ____________________

Engine Model	No. Cyls. & Valve Location	Bore & Stroke	Piston Disp. Cu. In.	Compression Ratio	Horse Power @ R.P.M.	Torque Ft. Lb. @ R.P.M.	GOVERNOR		Normal Oil Pressure	
							No-Load Setting R.P.M.	Full-Load Setting R.P.M.		

TUNE UP & VALVE SPECIFICATIONS

Engine Model	Spark Plugs		Ignition Timing		Valve Face Angle	Valve Lash		Valve Spring Pressure In. Length		
	Type	Gap	Timing Mark	Location		Intake	Exhaust			

ENGINE TIGHTENING SPECIFICATIONS*

* Torque specifications are for clean and lightly lubricated threads only. Dry or dirty threads produce increased friction which prevents accurate measurement of tightness.

Engine Model	Cyl. Head Ft. Lbs.	Exh. Man. Ft. Lbs.	Main Bear Cap Ft. Lbs.	Flywheel to Crankshaft Ft. Lbs.	Crankshaft Pulley Ft. Lbs.	Camshaft End Nut Ft. Lbs.	Conn. Rod Ft. Lbs.	Injector Bolts to Cyl. Head Ft. Lbs.	Pre-combustion Chamber Ft. Lbs.	Glow Plugs Ft. Lbs.

CRANKSHAFT AND BEARINGS
UNIT VI-B

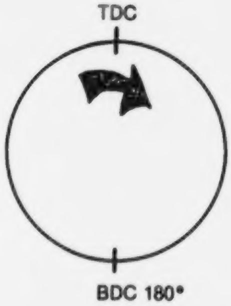
ASSIGNMENT SHEET #1 — DETERMINE PISTON LOCATION, STROKE POSITION, AND VALVE ADJUSTMENT OF A FOUR-CYCLE FOUR CYLINDER ENGINE

Assume that you are adjusting the valves on an engine with a firing order of 1-3-4-2. The #1 piston is at top dead center (TDC) compression stroke.

A. Write the last half of the numbers of the firing order below the first half of the numbers to find the corresponding cylinders.

B. Draw the location of each of the pistons under the conditions mentioned above on Figure 1.

FIGURE 1



C. Based on the condition of the engine mentioned above, tell which stroke each of the pistons is occupying.

No. 1 piston ______________________

No. 2 piston ______________________

No. 3 piston ______________________

No. 4 piston ______________________

ASSIGNMENT SHEET #1

D. On the engine mentioned above, which valves can be adjusted when the #1 piston is at TDC? Place an "X" beside each valve that can be adjusted.

	Intake	Exhaust
No. 1 cylinder	________	________
No. 2 cylinder	________	________
No. 3 cylinder	________	________
No. 4 cylinder	________	________

CRANKSHAFT AND BEARINGS
UNIT VI-B

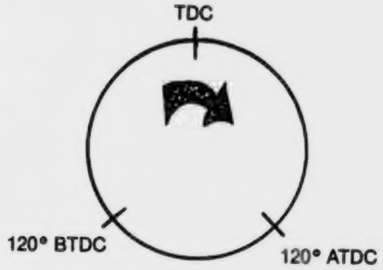
ASSIGNMENT SHEET #2 — DETERMINE PISTON LOCATION, STROKE POSITION, AND VALVE ADJUSTMENT OF A FOUR-CYCLE SIX CYLINDER ENGINE

Assume that you are adjusting the valves on an engine with a firing order of 1-5-3-6-2-4. The #1 piston is at top dead center (TDC) compression stroke.

A. Write the last half of the numbers of the firing order below the first half of the numbers to find the corresponding cylinders.

B. Draw the location of each of the pistons under the conditions mentioned above on Figure 1.

FIGURE 1



C. Based on the condition of the engine mentioned above, tell which stroke each of the pistons is occupying.

No. 1 piston ______________________________

No. 2 piston ______________________________

No. 3 piston ______________________________

No. 4 piston ______________________________

No. 5 piston ______________________________

No. 6 piston ______________________________

ASSIGNMENT SHEET #2

D. On the engine mentioned above, which valves can be adjusted when the #1 piston is at TDC? Place an "X" beside each valve that can be adjusted.

	Intake	Exhaust
No. 1 cylinder	____________	____________
No. 2 cylinder	____________	____________
No. 3 cylinder	____________	____________
No. 4 cylinder	____________	____________
No. 5 cylinder	____________	____________
No. 6 cylinder	____________	____________

CRANKSHAFT AND BEARINGS
UNIT VI-B

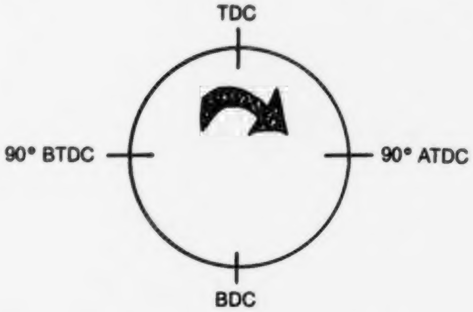
ASSIGNMENT SHEET #3 — DETERMINE PISTON LOCATION, STROKE POSITION, AND VALVE ADJUSTMENT OF A FOUR-CYCLE EIGHT CYLINDER ENGINE

Assume that you are adjusting the valves on an engine with a firing order of 1-8-6-4-2-7-5-3. The #2 piston is at top dead center (TDC) compression stroke.

A. Write the last half of the numbers of the firing order below the first half of the numbers to find the corresponding cylinders.

B. Draw the location of each of the pistons under the conditions mentioned above on Figure 1.

FIGURE 1



C. Based on the condition of the engine mentioned above, tell which stroke each of the pistons is occupying.

No. 1 piston ______

No. 2 piston ______

No. 3 piston ______

No. 4 piston ______

No. 5 piston ______

No. 6 piston ______

No. 7 piston ______

No. 8 piston ______

ASSIGNMENT SHEET #3

D. On the engine mentioned above, which valves can be adjusted when the #1 piston is at TDC? Place an "X" beside each valve that can be adjusted.

	Intake	Exhaust
No. 1 cylinder		
No. 2 cylinder		
No. 3 cylinder		
No. 4 cylinder		
No. 5 cylinder		
No. 6 cylinder		
No. 7 cylinder		
No. 8 cylinder		

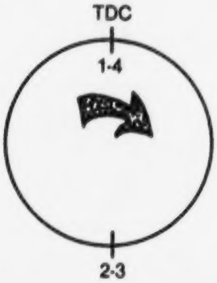
CRANKSHAFT AND BEARINGS
UNIT VI-B

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1-3
4-2

B.



C. No. 1 piston — TDC, finished compression, start power
No. 2 piston — BDC, finished power, start exhaust
No. 3 piston — BDC, finished intake, start compression
No. 4 piston — TDC, finished exhaust, start intake

D.

	Intake	Exhaust
No. 1 cylinder	X	X
No. 2 cylinder	X	
No. 3 cylinder		X
No. 4 cylinder		

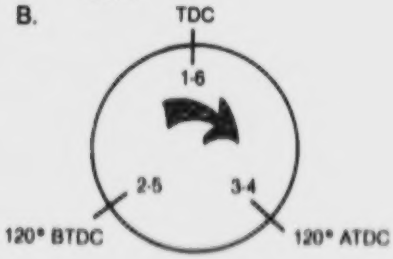
Cannot adjust valves on No. 4 cylinder because both valves are open (overlap)

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

A. 1-5-3
6-2-4

B.



C. No. 1 piston — TDC, finished compression, start power
No. 2 piston — Exhaust
No. 3 piston — Intake
No. 4 piston — Power
No. 5 piston — Compression
No. 6 piston — TDC, finished exhaust, start intake

D.

	Intake	Exhaust
No. 1 cylinder	X	X
No. 2 cylinder	X	
No. 3 cylinder		X
No. 4 cylinder	X	
No. 5 cylinder		X
No. 6 cylinder		

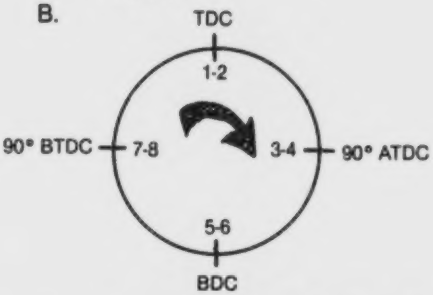
Cannot adjust valves on No. 6 cylinder because both valves are open (overlap)

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

A. 1-8-6-4
2-7-5-3

B.



C. No. 1 piston — TDC, finished exhaust, start intake
No. 2 piston — TDC, finished compression, start power
No. 3 piston — Intake
No. 4 piston — Power
No. 5 piston — BDC, finished intake, start compression
No. 6 piston — BDC, finished power, start exhaust
No. 7 piston — Compression
No. 8 piston — Exhaust

D.

	Intake	Exhaust
No. 1 cylinder	Valve Overlap	
No. 2 cylinder	X	X
No. 3 cylinder		X
No. 4 cylinder	X	
No. 5 cylinder		X
No. 6 cylinder	X	
No. 7 cylinder		X
No. 8 cylinder	X	

CRANKSHAFTS AND BEARINGS
UNIT VI-B

JOB SHEET #1 — REMOVE A CRANKSHAFT

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Engine
6. Marking set

   Example: Punch, chisel, letter or number marking set

7. Lifting device
8. Worksheets #1 and #2

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Refer to Unit III-B, Piston and Connecting Rod Assemblies, for piston removal information.)

1. Place engine in an engine stand. (Figure 1)

JOB SHEET #1

FIGURE 1

2. Mark main bearing caps and side of engine block, if necessary, for proper replacement.

3. If the main bearing capscrews have locking tangs, bend them back with an appropriate tool. (Figure 2)

FIGURE 2

JOB SHEET #1

4. Locate the main bearing capscrews and unscrew them in the proper sequence. (Figure 3)

FIGURE 3

5. Take the main bearing capscrews and lock plates out of the main bearing caps and place them on a workbench in the proper sequence. (Figure 4)

FIGURE 4

JOB SHEET #1

6. Use a pry bar or large screwdriver to remove the main bearing caps from the crankshaft main bearing journals; place them on the work bench. (Figures 5 and 6)

FIGURE 5

Loosening Main Bearing Cap from Dowel Pins

FIGURE 6

Using Pry Bar to Loosen Main Bearing Cap from Dowel Ring

7. If the main bearing did not come out with the main bearing cap, remove it from the main bearing journal. Place with corresponding main bearing cap. (Figure 7)

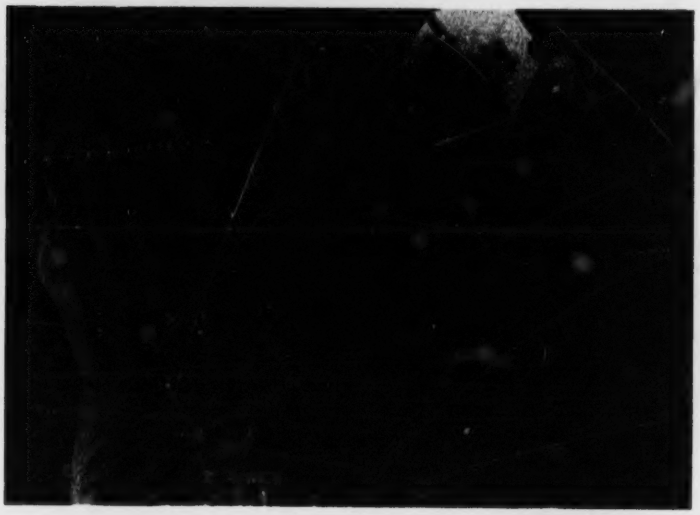
FIGURE 7

Obtain instructor's initials here ____________ before proceeding to next step.

JOB SHEET #1

8. Install a protective lifting device around the two middle throws of the crankshaft. (Figure 8)

FIGURE 8



9. Lift the crankshaft from the cylinder block; stand crankshaft on flywheel hub and secure to wall or work bench.

10. Remove the upper main bearing shells from the cylinder block and place them on the work bench with their corresponding main bearing caps.

    (NOTE: Also remove dowel rings at this time.)

    Obtain instructor's initials here ____________.

CRANKSHAFTS AND BEARINGS
UNIT VI-B

JOB SHEET #2 — CLEAN AND MEASURE A CRANKSHAFT AND BEARINGS

A. Tools and materials

1. Safety glasses
2. Clean shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Crankshaft
6. Outside micrometer
7. Inside micrometer
8. Cleaning rod
9. Worksheets #1 and #2

B. Procedure

(CAUTION: Follow all shop safety procedures.)

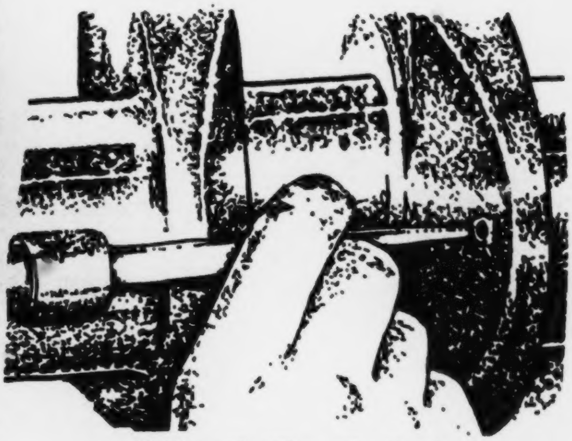
1. Clean outside of crankshaft, paying close attention to bearing surfaces.

   (NOTE: Some crankshafts have pipe plugs in the drillings of the crank. Remove these and use a cleaning rod and rag to clean them. Then lightly oil the threads and reinstall. Figures 1 and 2.)

FIGURE 1

Cleaning Oil Passages in Crankshaft

FIGURE 2



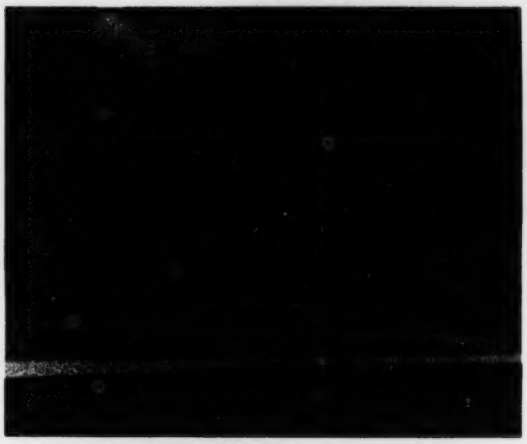
Staking a Pipe Plug with a Punch

JOB SHEET #2

2. Check with appropriate service manual for main and rod bearing journal dimensions, and record specification in appropriate blanks on Worksheet #1.

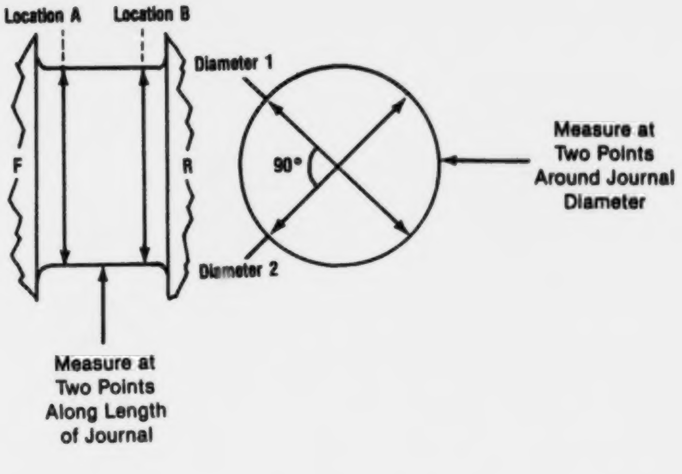
3. Measure the crankshaft bearing journals with an outside micrometer. (Figure 3)

FIGURE 3


Outside Micrometer
Crankshaft Journal

4. Measure the crankshaft journals in at least two points along length of journal (taper), and at least two points around diameter of the journal (out-of-roundness). (Figure 4)

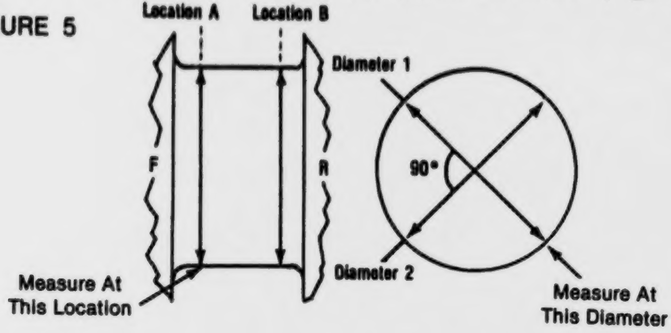
FIGURE 4


Location A
Location B
Diameter 1
F
R
90°
Diameter 2
Measure at Two Points Around Journal Diameter
Measure at Two Points Along Length of Journal

JOB SHEET #2

5. Measure journal, main or rod journal, at location A - diameter 1, and record the measurement in column A of the appropriate worksheet. (Figure 5)

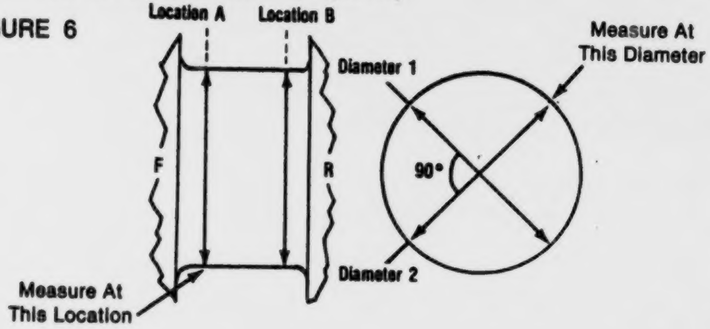
FIGURE 5


Location A
Location B
Diameter 1
F
R
90°
Diameter 2
Measure At This Location
Measure At This Diameter

(NOTE: You will take two measurements in location A.)

6. Measure journal at location A — diameter 2. Record measurement in column A of the appropriate worksheet. (Figure 6)

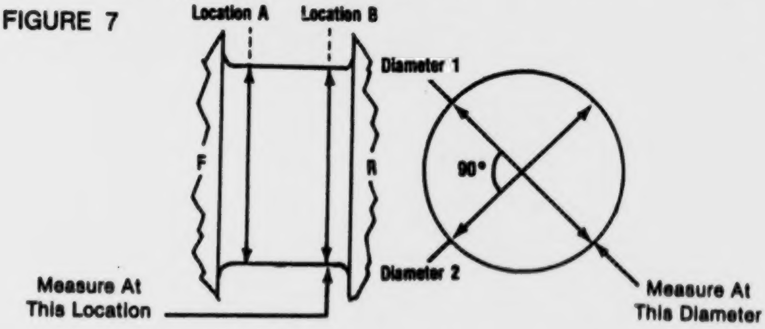
FIGURE 6


Location A
Location B
Measure At This Diameter
Diameter 1
F
R
90°
Diameter 2
Measure At This Location

7. Subtract the smaller measurement in column A from the larger to calculate journal out-of-roundness; record measurement in appropriate blank of worksheet.

8. Measure journal at location B — diameter 1, and record measurement in column B of the appropriate worksheet. (Figure 7)

FIGURE 7

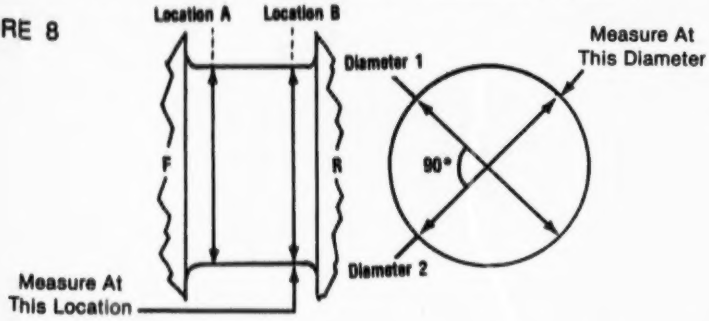

Location A
Location B
Diameter 1
F
R
90°
Diameter 2
Measure At This Location
Measure At This Diameter

(NOTE: You will take two measurements in location B.)

JOB SHEET #2

9. Measure journal at location B — diameter 2 (90° from diameter 1). Record measurement in column B of the appropriate worksheet. (Figure 8)

FIGURE 8



10. Subtract the smaller measurement in column B from the larger to calculate journal out-of-roundness; record measurement in appropriate blank of worksheet.

11. Subtract the smaller measurement of column A or B from the larger measurement of column A or B to get journal taper; record measurement in column C of the appropriate worksheet.

    Obtain instructor's initials here ____________ before proceeding to next step.

12. Measure remaining journals of the crankshaft, and record the measurements in the appropriate blanks of the worksheets.

13. Record journal outside diameter in column E of the appropriate worksheet.

14. Install main bearings into cylinder block and main cap, and install main caps into the block.

15. Torque main caps to specifications.

16. Measure inside diameter of the main bearing with an inside micrometer, telescoping gauge, or bore gauge.

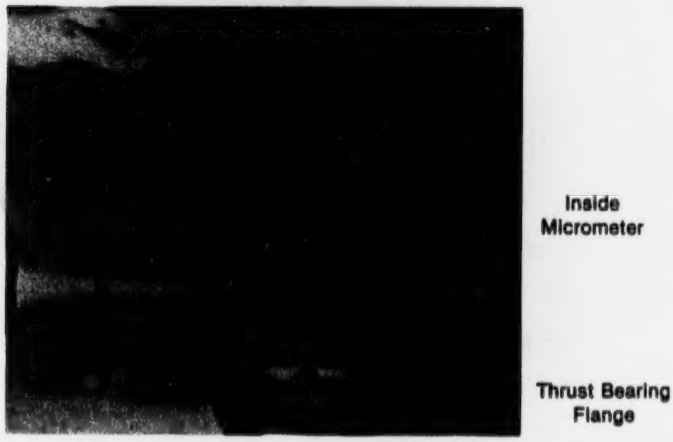
17. Record the measurement of the inside diameter in column D of Worksheet #1.

18. Subtract the measurement in column E from the measurement in column D to calculate bearing clearance, and record measurement into column F of Worksheet #1.

JOB SHEET #2

19. Measure the thrust bearing flange of the crankshaft with an inside micrometer. (Figure 9)

FIGURE 9


Inside
Micrometer
Thrust Bearing
Flange

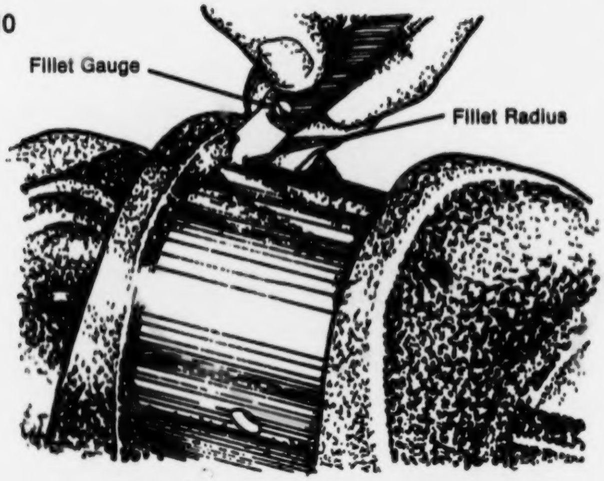
(NOTE: Check with appropriate service manual for permissible wear of the thrust flange.)

20. Record the thrust flange measurement in column H of Worksheet #1.

21. Measure the crankshaft fillet with a fillet gauge. (Figure 10)

(NOTE: Check with appropriate service manual for permissible wear of the fillet.)

FIGURE 10

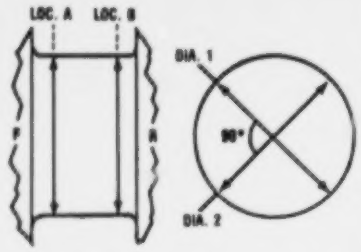

Fillet Gauge
Fillet Radius

JOB SHEET #2

22. Record fillet measurement in column G of Worksheet #1.
23. Record rod bearing journal outside diameter in column E of Worksheet #2.
24. Install rod bearings into connecting rod and rod cap.
25. Install rod cap with bearing onto the connecting rod, and torque to specifications.
26. Measure the rod bearing inside diameter with an inside micrometer, telescoping gauge, or bore gauge.
27. Record rod bearing inside diameter measurement in column D of Worksheet #2.
28. Subtract measurement of column E from measurement of column D to get rod bearing clearance.
29. Record rod bearing clearance in column F of Worksheet #2.
30. Complete Worksheets #1 and #2, and have instructor initial when completed.

    Obtain instructor's initials here ____________.

CRANKSHAFT AND BEARING EVALUATION WORKSHEET



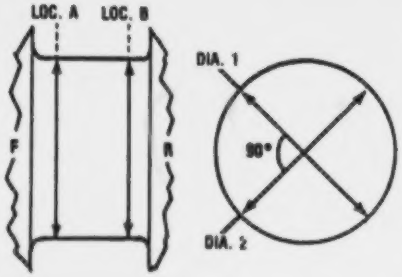
Main Bearing Journal Measurements

SPECIFICATIONS	
Main Journal	
Permissible Bearing Clearance	
Permissible Journal Wear	
Permissible Out-of-Round	
Permissible Taper	

	COLUMN A			COLUMN B			COLUMN C	COLUMN D	COLUMN E	COLUMN F	COLUMN G	COLUMN H
Journal	Location A Diameter 1	Location A Diameter 2	Out-of-Roundness	Location B Diameter 1	Location B Diameter 2	Out-of-Roundness	Taper	Main Bearing I.D.	Main Bearing Journal O.D.	Bearing Clearance	Fillet Condition	Thrust Flange Wear
FRONT MAIN											Good	
INT. #1											Bad	
INT. #2												
CENTER MAIN												
INT. #3												
INT. #4												
REAR MAIN												

Instructor's Initials ____________

CRANKSHAFT AND BEARING EVALUATION WORKSHEET



Rod Bearing Journal Measurements

SPECIFICATIONS	
Connecting-Rod Journal Diameter	
Permissible	
Permissible Out-Of-Round	
Permissible Journal Wear	
Permissible Taper	

	COLUMN A			COLUMN B			COLUMN C	COLUMN D	COLUMN E	COLUMN F
JOURNAL	Location A Diameter 1	Location A Diameter 2	Out-of-Roundness	Location B Diameter 1	Location B Diameter 2	Out-of-Roundness	Taper	Rod Bearing I.D.	Rod Bearing Journal I.D.	Bearing Clearance
#1 PIN										
#2 PIN										
#3 PIN										
#4 PIN										
#5 PIN										
#6 PIN										
#7 PIN										
#8 PIN										

Instructor's Initials ____________

CRANKSHAFT AND BEARINGS
UNIT VI
WORKSHEET #2

CRANKSHAFTS AND BEARINGS
UNIT VI-B

JOB SHEET #3 — INSTALL BEARINGS AND CRANKSHAFT

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tool set
4. Appropriate service manual
5. Engine
6. Pry bar
7. Torque wrench
8. Dial indicator
9. Plastigage®
10. Lubriplate®
11. New engine bearings
12. New lockplates, if used
13. Lifting device

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Check appropriate service manual for correct crankshaft installation procedure for engine being worked on.)

1. Place upper crankshaft bearing halves in engine block and lubricate bearings. (Figure 1)

JOB SHEET #3

FIGURE 1

(CAUTION: Do not put grease on back side of bearing.)

2. Line up oil holes in block and oil holes in bearing; make sure bearing locking device on bearing lines up with recess block. (Figure 2)

FIGURE 2

JOB SHEET #3

3. Using a protective lifting device, place crankshaft in block. (Figure 3)

FIGURE 3

(CAUTION: Use care not to damage crankshaft or engine bearings.)

Obtain instructor's initials here ____________ before proceeding to next step.

4. Install thrust bearings into place.
5. Place lower bearing halves in main bearing caps.
6. Place all main bearing caps except #1 in place. (Figure 4)

FIGURE 4

JOB SHEET #3

7. Using the proper size Plastigage®, break off a section long enough to go across main bearing.

8. Place the Plastigage® off center on the bearing and place on #1 journal.

9. Torque main bearing caps to specifications.

10. Loosen main bearing cap #1 and remove.

11. Compare flattened Plastigage® to Plastigage® scale.

12. Repeat for the remaining journals.

    (NOTE: You will replace each cap and torque to specifications after Plastigaging® the journal; then rotate crankshaft to make sure it turns freely.) (Figure 5)

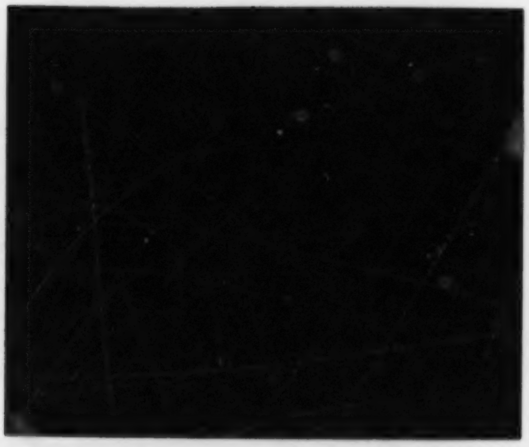
    FIGURE 5

Obtain instructor's initials here ____________ before proceeding to next step.

13. With all main bearing caps torqued to specifications, take a pry bar and pry the crankshaft forward until it stops; remove pry bar, set up dial indicator at the rear of the block and zero the indicator. (Figure 6)

JOB SHEET #3

FIGURE 6



14. Pry the crankshaft rearward and note indicator reading.

    (NOTE: Refer to manufacturer's specifications for proper end play.)

15. Remove all lower main bearing halves and apply Lubriplate® to main bearings; retorque all main bearing capscrews to specifications. (Figure 7)

    FIGURE 7

Obtain instructor's initials here ____________.

CRANKSHAFT AND BEARINGS
UNIT VI-B

PRACTICAL TEST
JOB SHEET #1 — REMOVE A CRANKSHAFT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Placed engine in an engine stand.	______	______
4. Marked main bearing caps, if necessary.	______	______
5. Removed main bearing capscrews and caps.	______	______
6. Stored main bearing caps and main bearing together.	______	______
7. Installed lifting device to crankshaft.	______	______
8. Removed crankshaft from cylinder block.	______	______
9. Removed upper main bearing from cylinder block.	______	______
10. Stored upper main bearings with respective caps.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Crankshaft is removed from engine properly	4	3	2	1
Main bearings are marked with respective caps	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

D-381-B

CRANKSHAFT AND BEARINGS
UNIT VI-B

PRACTICAL TEST
JOB SHEET #2 — CLEAN AND MEASURE A CRANKSHAFT AND BEARINGS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Cleaned crankshaft journals and bores.	______	______
4. Measured main and rod journals with outside micrometer.	______	______
5. Measured journals for out-of-roundness.	______	______
6. Measured journals for taper.	______	______
7. Measured main and rod bearing inside diameter.	______	______
8. Subtracted journal outside diameter from bearing inside diameter to calculate bearing clearance.	______	______
9. Measured the fillet condition.	______	______
10. Measured thrust flange for wear.	______	______
11. Recorded out-of-roundness measurements on Worksheet #1 and #2.	______	______
12. Recorded journal taper on Worksheet #1 and #2.	______	______
13. Recorded bearing clearance on Worksheet #1 and #2.	______	______
14. Recorded bearing inside diameter.	______	______
15. Checked in/put away tools and materials.	______	______
16. Cleaned the work area.	______	______
17. Used proper tools correctly.	______	______
18. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
19. Practiced safety rules throughout procedure.	______	______
21. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Crankshaft is cleaned properly for measuring	4	3	2	1
Crankshaft main bearing journals are within specification	4	3	2	1
Crankshaft connecting rod journals are within specification	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

D-383-B

CRANKSHAFT AND BEARINGS
UNIT VI-B

PRACTICAL TEST
JOB SHEET #3 — INSTALL BEARINGS AND CRANKSHAFT

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Installed upper main bearing shell in block.	______	______
4. Lubricated the upper bearing shells.	______	______
5. Installed crankshaft into cylinder block.	______	______
6. Installed thrust bearings onto crankshaft.	______	______
7. Lubricated and installed lower main bearing shells.	______	______
8. Installed main bearing caps.	______	______
9. Torqued main bearing caps to specification.	______	______
10. Checked turning freeness of the crankshaft.	______	______
11. Checked crankshaft end-play.	______	______
12. Checked in/put away tools and materials.	______	______
13. Cleaned the work area.	______	______
14. Used proper tools correctly.	______	______
15. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
16. Practiced safety rules throughout procedure.	______	______
17. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Crankshaft is installed properly				
	4	3	2	1
Crankshaft end play is within specification				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

CRANKSHAFTS AND BEARINGS
UNIT VI-B

NAME ______________________ SCORE ____________________

TEST

1. Match the terms related to crankshaft and bearings with the correct definitions.

_____a. Made from a single billet of steel

_____b. The part of a shaft or axle in contact with the bearing

_____c. Two crankshaft webs and one crankpin

_____d. Forms the crank or throw between the crankpin and main journal

_____e. Outer end of crank throw

_____f. Reduces torsional stress on the crankshaft caused by power strokes and the loads on the engine

_____g. Balanced while at rest

_____h. Balanced against the rotary outward force at high speed

_____i. Full round sleeve normally used to support light loads

_____j. Half round sleeve normally used to support heavy loads

_____k. Measured difference between the inside diameter of the bearing and the outside diameter of the journal

_____l. Engine block without cylinder head and external accessories

_____m. Controls crankshaft end play

_____n. Two pistons in a four-cycle engine moving in the same direction but on different strokes

_____o. The order in which the cylinders deliver their power strokes

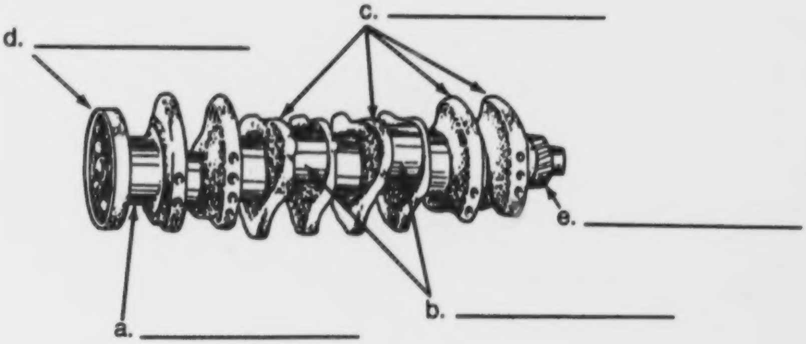
1. Bearing
2. Bearing clearance
3. Bushing
4. Corresponding cylinders
5. Crankpin
6. Crankshaft throw
7. Crankshaft web
8. Counterweight
9. Dynamically balanced
10. Fillet
11. Firing order
12. Integral crankshaft
13. Journal
14. Short block
15. Statically balanced
16. Thrust bearing
17. Vibration damper

TEST

_____p. Weights mounted on the crankshaft that reduce the vibration and bearing loads due to internal force

_____q. A curved joint between the journal and the web to add strength

2. Identify the parts of a crankshaft.



3. Match the arrangement of crankshaft throws on the right with the number of cylinders in the engine.

_____a.	Two and four cylinder	1. Throws 90°apart
_____b.	Three and six cylinder	2. Throws 180° apart
_____c.	Eight cylinder	3. Throws 120° apart

4. Arrange in order the steps in determining the corresponding cylinders of a four-cycle engine by placing the correct sequence numbers in the appropriate blank.

_____a. Write the last half of the cylinder numbers of the firing order below the first half of the numbers.

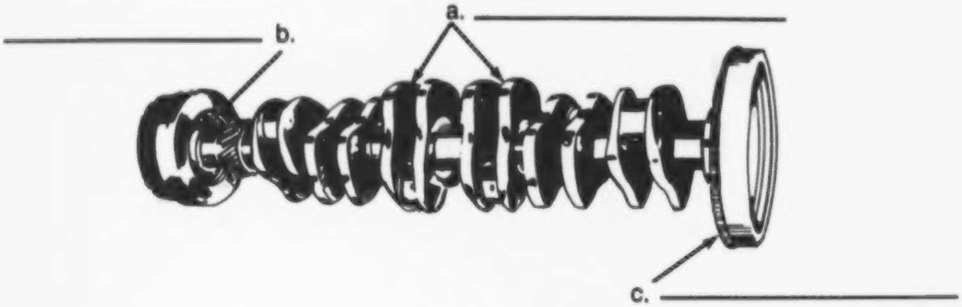
_____b. Place the corresponding cylinders on a chart.

_____c. Find the firing order of the engine.

_____d. Locate #1 cylinder on compression stroke, and its corresponding cylinder at top dead center.

TEST

5. Identify ways a crankshaft balance is maintained.



6. Select true statements concerning the lubrication of the crankshaft and surrounding parts by placing an "X" beside each statement that is true.

_____a. Oil pressure through crankshaft lubricates rod and main bearing.

_____b. Excess oil from rod and main bearing lubricates surrounding parts.

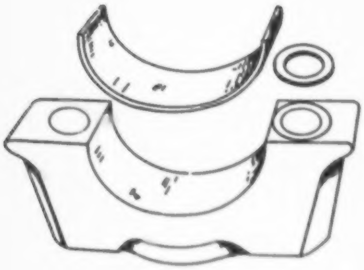
7. Name three materials used in making bearing linings.

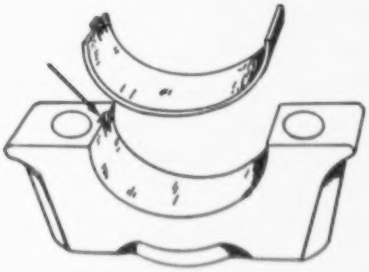
a. ____

b. ____

c. ____

8. Identify types of bearing locks.





a. ____________________ b. ____________________

TEST

9. Define bearing crush.

_____

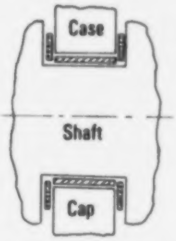
_____

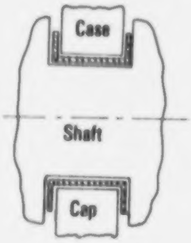
10. State the purpose of oil grooves in the bearing.

_____

_____

11. Identify types of thrust bearings.





a. _____ b. _____

12. List three engine indications of bearing failure.

a. _____

b. _____

c. _____

13. Match the percentages of bearing failure with the causes of bearing failure.

_____a.	Dirt	1. 9 percent
_____b.	Lack of lubrication	2. 14 percent
_____c.	Improper assembly	3. 16 percent
_____d.	Misalignment	4. 10 percent
_____e.	Overloading	5. 43 percent

TEST

14. Select true statements concerning the functions of the flywheel by placing an "X" beside each statement that is true.

______a. Provide a drive for starter via clutch

______b. Smooths out speed of crankshaft

______c. Serves as a facing for engine cylinder head

______d. Stores energy for momentum between power strokes

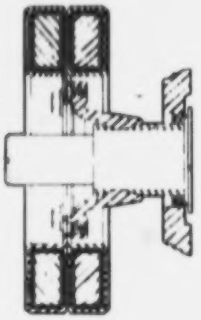
______e. Provides a drive for starter via ring gear

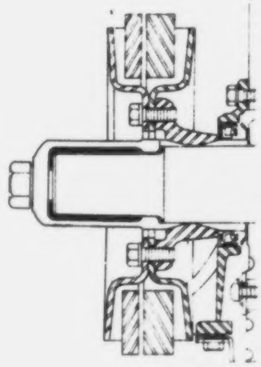
______f. Stores ring gear for momentum between power strokes

______g. Transmits power to driven machine

______h. Serves as a facing for engine clutch

15. Identify types of vibration dampers.





a. ______________________________ b. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

16. Determine piston location, stroke position and valve adjustment of a four-cycle four cylinder engine. (Assignment Sheet #1)

17. Determine piston location, stroke position and valve adjustment of a four-cycle six cylinder engine. (Assignment Sheet #2)

18. Determine piston location, stroke position and valve adjustment of a four-cycle eight cylinder engine. (Assignment Sheet #3)

TEST

20. Demonstrate the ability to:

    a. Remove a crankshaft. (Job Sheet #1)

    b. Inspect and measure a crankshaft and bearings. (Job Sheet #2)

    c. Install bearings and crankshaft. (Job Sheet #3)

CRANKSHAFT AND BEARINGS
UNIT VI-B

ANSWERS TO TEST

1. a. 12
   b. 13
   c. 6
   d. 7
   e. 5
   f. 17
   g. 15
   h. 9
   i. 3
   j. 1
   k. 2
   l. 14
   m. 16
   n. 4
   o. 11
   p. 8
   q. 10

2. a. Main bearing journals
   b. Connecting rod bearing journals
   c. Connecting rod counterweights
   d. Flywheel hub or flange
   e. Crankshaft gear
   f. Crankshaft throw

3. a. 2
   b. 3
   c. 1

4. a. 2
   b. 3
   c. 1
   d. 4

5. a. Counterweights
   b. Vibration damper
   c. Flywheel

6. a, b

7. a. Tin or lead base babbit
   b. Copper or aluminum alloys
   c. Multilayers of copper or aluminum alloys and silver combinations

8. a. Dowel ring
   b. Lip slot

9. Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened

ANSWERS TO TEST

10. Bearing oil grooves carry the oil through to the connecting rod

11. a. Separate thrust washers
    b. Thrust flanges on bearings

12. a. Drop in lubricating oil pressure
    b. Excessive oil consumption
    c. Engine noise — Rhythmic knock

13. a. 5
    b. 3
    c. 2
    d. 4
    e. 1

14. b, d, e, g, h

15. a. Viscous
    b. Rubber-element

16.-18. Evaluated to the satisfaction of the instructor

19. Performance skills evaluated to the satisfaction of the instructor

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify the components of lubrication systems and match the components with the purposes. The student should also be able to check oil pressure and change an oil filter. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to lubrication systems with the correct definitions.
2. Select statements concerning the characteristics of a good engine oil.
3. Complete statements explaining SAE viscosity number.
4. Select true statements concerning the API classification system.
5. Select true statements concerning engine oil.
6. List rules for selection and use of engine oil.
7. Complete statements concerning oil contamination.
8. Match diagnostic tests related to oil analysis with the descriptions.
9. Identify types of oil filters.
10. List functions of the lubrication system.

OBJECTIVE SHEET

11. Identify components of the lubrication system.

12. Match components related to lubrication systems with the purposes.

13. Match lubricating valves with the purposes.

14. Name types of oil pumps.

15. Distinguish between internally and externally mounted oil coolers.

16. Select true statements concerning mechanical and electrical oil pressure indicating systems.

17. Select true statements concerning oil temperature indicating systems.

18. Match terms related to components of an oil pressure shutdown or alarm circuit with the correct definitions.

19. Arrange in order the steps of operation of the oil pressure shutdown or alarm circuit.

20. Demonstrate the ability to:

    a. Check oil pressure on a live engine. (Job Sheet #1)

    b. Change an oil filter. (Job Sheet #2)

LUBRICANTS AND LUBRICATING SYSTEMS
UNIT I-C

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet and Handout #1.

F. Discuss information sheet and Handout #1.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Invite company representative to discuss lubricating oils.

   2. Make a display of different oil filter types.

   3. Discuss oil analysis and demonstrate taking samples.

   4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Fundamentals of Service: Fuels, Lubricants, and Coolants.* 4th ed. Moline, IL: Deere and Co., 1980.

B. Schulz, Erich V. *Diesel Mechanics.* 2nd ed. Dallas: McGraw-Hill Book Company, 1983.

C. *Troubleshooting and Repair Manual-L10 Engines.* Columbus, IN: Cummins Engine Company, Inc., 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Text

1. *Oil and Your Engine*
   Order #SEBD0640
   Caterpillar, Inc.
   Literature Order Section
   P.O. Box 5319
   Morton, IL 61550

B. Filmstrips

1. *Basic Diesel Engine Operation and Maintenance*
   Order #B-475
   Teaching Aids Incorporated
   P.O. Box 1798
   Costa Mesa, CA 92628-0798

2. *Basic Engine Lubrication*
   Order #SESV1035
   Caterpillar, Inc.
   Literature Order Section
   P.O. Box 5319
   Morton, IL 61550

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

INFORMATION SHEET

I. **Terms and definitions**

   A. Additives — Certain properties added to oil to provide extra performance

   B. API — American Petroleum Institute

   C. ASTM — American Society for Testing Materials

   D. Friction — Resistance to movement between any two objects placed in contact with each other

   E. Gallery — Pipe or passageway in the engine used to carry engine oil from one area to another

   F. MIL — Oil specifications prepared by the Ordinance Department of the Military Forces

   G. Multigrade oils — Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

   H. SAE — Society of Automotive Engineers

   I. Viscometer — Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

   J. Viscosity — A measure of the fluidity of an oil at a given temperature

II. **Characteristics of good engine oil**

   A. Keeps a protective film on moving parts

   B. Resists breakdown at high temperatures

   C. Resists corrosion and rusting

   D. Prevents carbon buildup

   E. Prevents sludge formation

   F. Flows easily at low temperatures

   G. Resists foaming

   H. Resists breakdown after long use

INFORMATION SHEET

III. **SAE viscosity number**

A. Oils vary in viscosity as temperatures change.

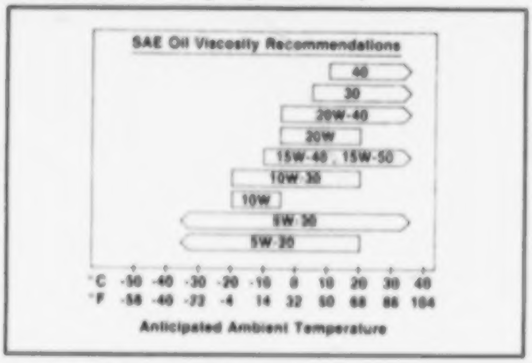
(NOTE: Oil becomes more fluid as temperatures increase and less fluid as temperatures decrease.)

B. Lighter oils for winter use are specified at 0°F and carry a 5w, 10w, or 20w symbol.

(NOTE: Specifications are determined by time of flow through an instrument, such as a Saybolt viscometer, in seconds.)

C. Heavier oils are specified at 210°F and carry a 20, 30, 40, or 50 viscosity number.

(NOTE: Compounded oils, called multi-grade oils, behave as light oils in cold temperatures and heavier oils at high temperatures, for example 15w-40 can replace four single grade oils.)



(Courtesy of Cummins Engine Company, Inc.)

IV. **API classification system** (Handout #1)

A. Joint effort of API, ASTM, and SAE organizations.

B. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, the petroleum industry, and the customer.

V. **Facts about oil**

A. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted.

B. Multi-viscosity oils are not always preferred.

C. Black oil does not mean time for an oil change.

D. Buy quality oil filters as recommended by machine operator's manual.

INFORMATION SHEET

E. Oil oxidation results in thicker oil.

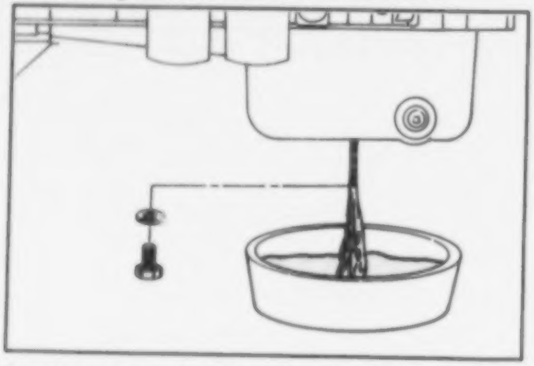
F. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice.

G. Following operator's manual recommendations is critical to insure good performance.

VI. **Selection and use of oils for best engine performance**

A. Use brands which meet engine manufacturer's specifications.

B. Drain and change at recommended intervals.



(Courtesy of Cummins Engine Company, Inc.)

C. Select oils which have been performance tested.

D. Never mix oils of various MIL specifications.

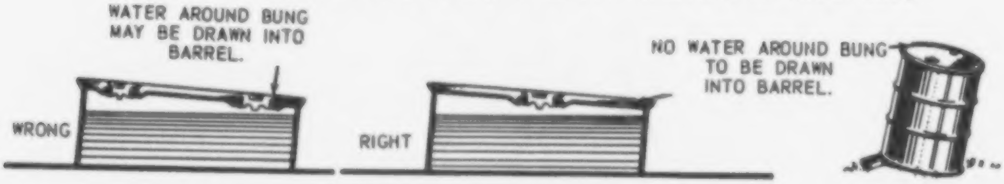
E. Bring engine up to normal operating temperature each time it is used.

F. Keep oil containers covered, sealed, and protected to prevent contamination.

VII. **Common sources of oil contamination**

A. Storing and handling

(NOTE: Keep all covers and spouts on containers when not in use.)


WATER AROUND BUNG MAY BE DRAWN INTO BARREL.
WRONG
RIGHT
NO WATER AROUND BUNG TO BE DRAWN INTO BARREL.

(Reproduced by permission of Deere & Company, © 1980 Deere & Company. All rights reserved.)

INFORMATION SHEET

B. Dust from air that is breathed into engine

(NOTE: Clean or replace air cleaner and breather on oil filter regularly.)

C. Improper engine warm-up

(NOTE: Partially burned fuel blows by the piston rings and into the crankcase.)

D. Antifreeze leaking into oil supply

(NOTE: Antifreeze in crankcase causes sludge.)

E. Oxidation

(NOTE: Hydrocarbons in the oil combine with oxygen in the air to produce organic acids.)

F. Carbon particles

(NOTE: Carbon is created when oil around the upper cylinder walls is burned during combustion.)

G. Engine wear

(NOTE: Tiny metal particles are constantly being worn off bearings and other parts.)

H. Fuel dilution

VIII. **Lubricating oil analysis and diagnostic tests**

A. Wear analysis — Detects component wear and dirt contamination

B. Chemical and physical tests — Detect water, fuel, and antifreeze

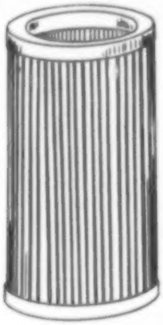
C. Oil condition analysis — Detects soot and sulfur, oxidation, and nitration products

INFORMATION SHEET

IX. **Types of oil filters**

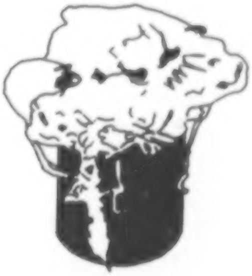
(NOTE: The most common measurement used to determine degree of filtration is a micron, which is approximately 40 millionths of an inch.)

A. Surface



(NOTE: The surface filter is composed of a specially treated micrometric cellulose paper. Oil passes straight through tiny holes.)

B. Depth



Cotton

(NOTE: Oil moves in many directions before passing through filter to lubrication system.)

X. **Functions of the lubrication system** (Transparency 1)

A. Reduces friction between moving parts

B. Absorbs and dissipates heat

C. Seals the piston rings and cylinder walls

D. Cleans and flushes moving parts

E. Helps deaden the noise of the engine by absorbing shock.

INFORMATION SHEET

XI. **Components of the lubrication system** (Transparency 2)

A. Oil galleries

B. Oil filter

C. Pressure regulating valve

D. Oil pump

E. Oil pan

F. Pressure gauge

G. Oil cooler

XII. **Purposes of components of the lubrication system**

A. Pressure gauge — Indicates oil pressure during engine operation

B. Pressure regulating valve — Limits the maximum oil pressure

C. Oil cooler — Engine coolant flows through the unit and helps dissipate the heat in the engine oil

D. Oil filter — Strains the engine oil by removing abrasive particles

E. Oil galleries — Carry engine oil from one area to another

F. Oil pan — Provides a reservoir for the engine oil

G. Oil pump — Forces oil under pressure to various parts of the engine for lubrication

XIII. **Purposes of lubricating valves** (Transparency 3)

A. Pressure relief — Bypasses excess oil when the engine is cold or when the pressure exceeds approximately 100 PSI

B. Pressure regulator — Limits oil gallery pressure to about 45 to 50 PSI

C. By-pass — Bypasses lubricating components when they become restricted

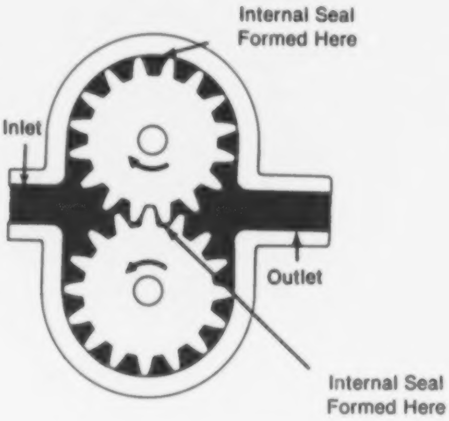
D. Antidrain check — Prevents oil from draining from the filter when the engine is stopped

INFORMATION SHEET

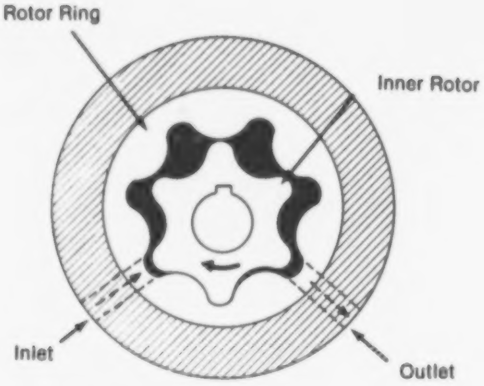
XIV. **Types of oil pumps**

(NOTE: All types are positive displacement pumps.)

A. Gear


Internal Seal Formed Here
Inlet
Outlet
Internal Seal Formed Here

B. Rotor


Rotor Ring
Inner Rotor
Inlet
Outlet

XV. **Oil cooler circulation** (Transparency 4)

A. Internally mounted — Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated

B. Externally mounted — Both water and oil are pumped through the oil cooler

(NOTE: Oil coolers are also known as heat exchangers.)

XVI. **Oil pressure indicating systems**

A. Mechanical — Bourdon tube gauge which tends to straighten out when pressure is applied (Transparency 5)

INFORMATION SHEET

B. Electrical (Transparency 6)

1. Sending unit is at pressure source.

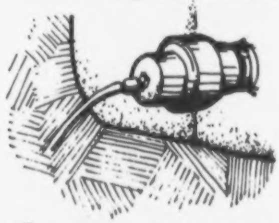
2. Indicating gauge is on control panel.

(NOTE: Electrical indicating systems may be three types: electromagnetic coil, heating coil, or pressure switch system.)

XVII. Oil temperature indicating system

A. Electromagnetic gauge is mounted in control panel

B. Variable resistor sending unit is mounted in oil pan

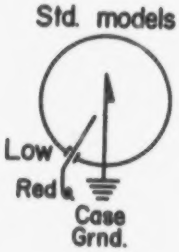


XVIII. Components of an oil pressure shutdown or alarm circuit

(NOTE: The following covers Murphy's 20 Series pressure gauges. The wiring and the type of magnetic switch will differ for various applications.)

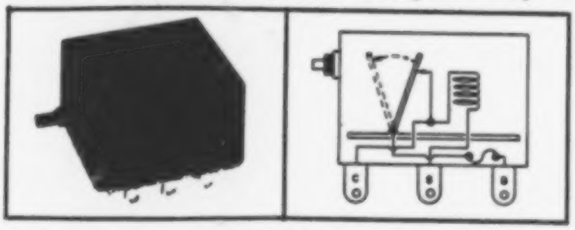
A. Swichgages® — A combination gauge and switch for alarm or shutdown of equipment

0 20 40 60
0 2 4 6
x 100
SSURE



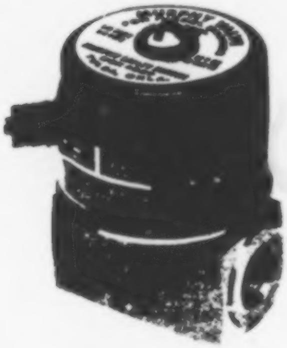
INFORMATION SHEET

B. Magnetic switch — Grounds magnetos; energizes relays and actuates valves



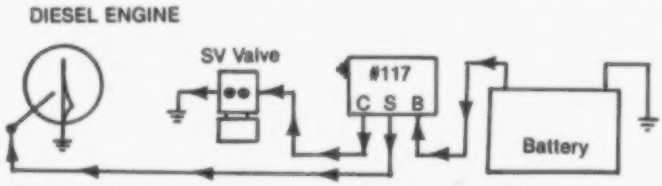
Circuitry

C. Fuel shutoff valve — Opens or closes when current is supplied, cutting off fuel to engine



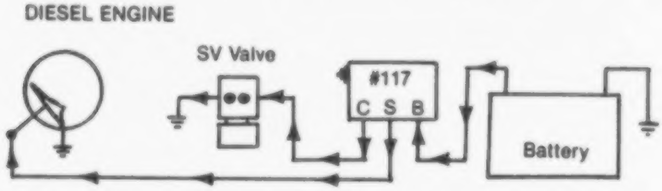
XIX. **Operation of the oil pressure shutdown or alarm circuit**

A. A fuel valve holding coil is wired through the magnetic switch.

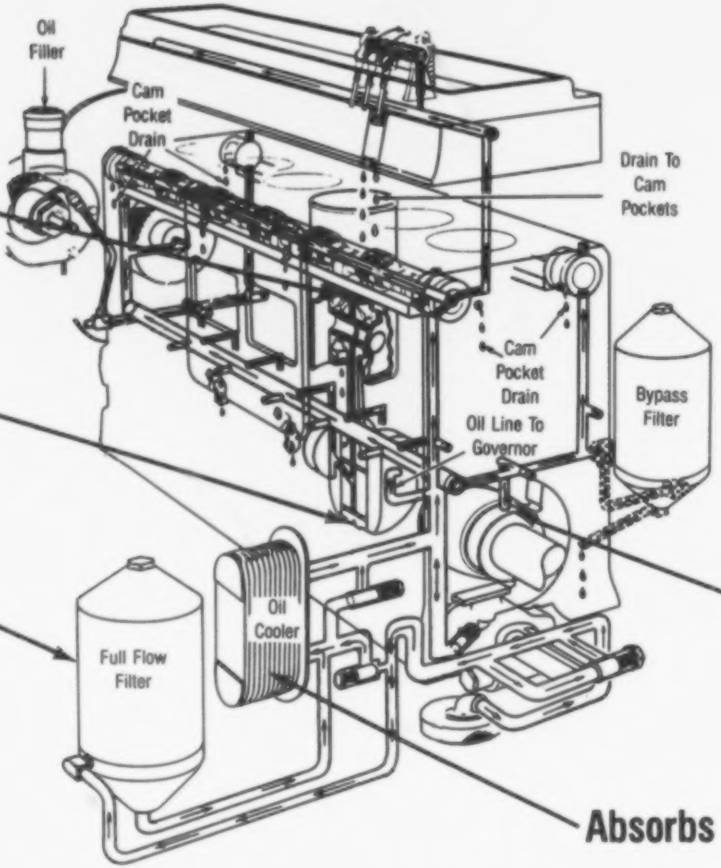

DIESEL ENGINE
SV Valve
#117
C S B
Battery

B. If oil pressure drops during operation, the pointer of the gauge contacts the low oil pressure adjustment screw, grounding the Swichgage®.

C. Grounding the Swichgage® causes the magnetic switch to open the circuit to the fuel shutoff solenoid at the injection pump.


DIESEL ENGINE
SV Valve
#117
C S B
Battery

Functions of the Lubrication System


Oil Filler
Cam Pocket Drain
Drain To Cam Pockets
Cam Pocket Drain
Oil Line To Governor
Bypass Filter
Oil Cooler
Full Flow Filter

Seals Piston Rings

Deadens Noise

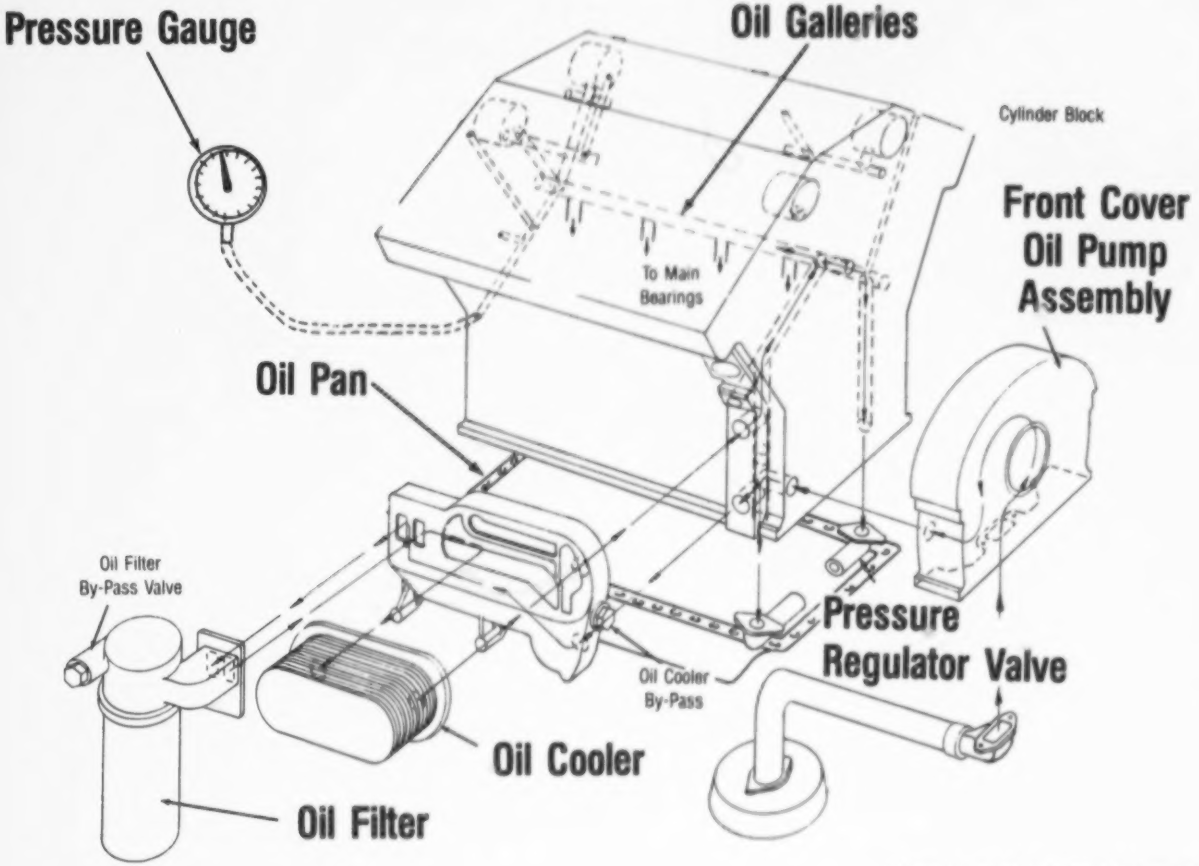
Cleans Oil

Reduces Friction and Wear

Absorbs Heat

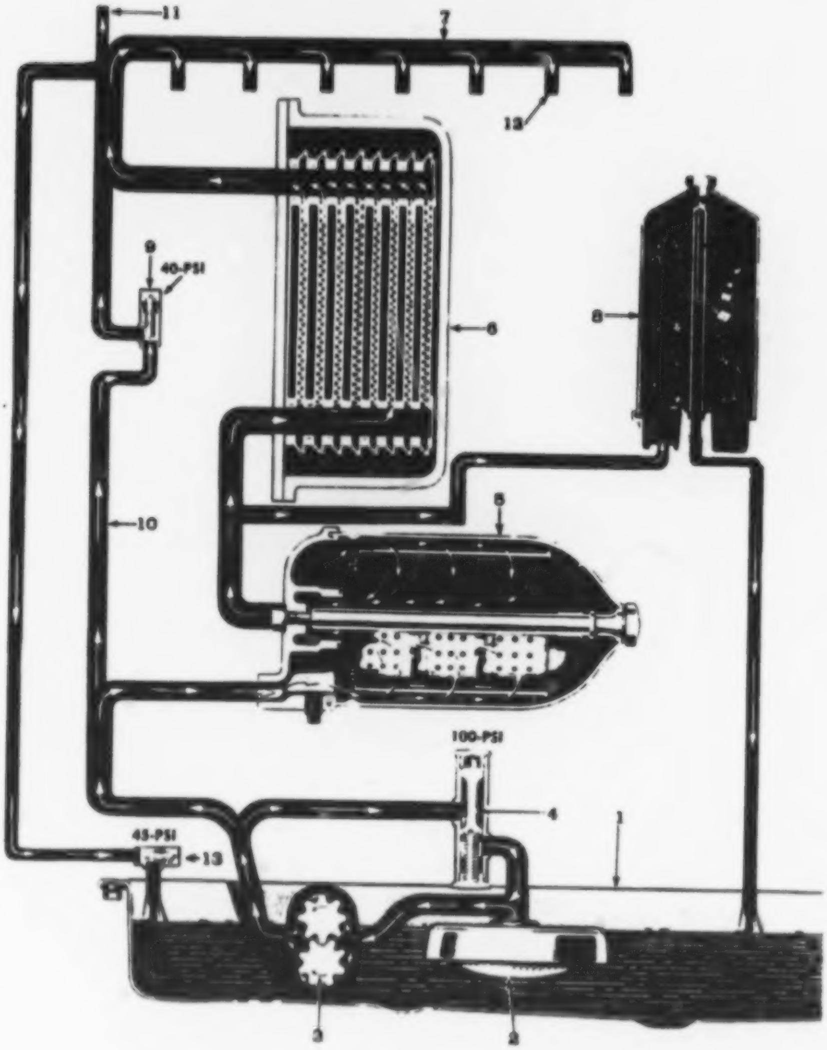
(Courtesy of Detroit Diesel Corporation.)

Components of the Lubrication System


Pressure Gauge
Oil Galleries
Cylinder Block
Front Cover
Oil Pump
Assembly
To Main
Bearings
Oil Pan
Oil Filter
By-Pass Valve
Pressure
Regulator Valve
Oil Cooler
By-Pass
Oil Cooler
Oil Filter

(Courtesy of Detroit Diesel Corporation.)

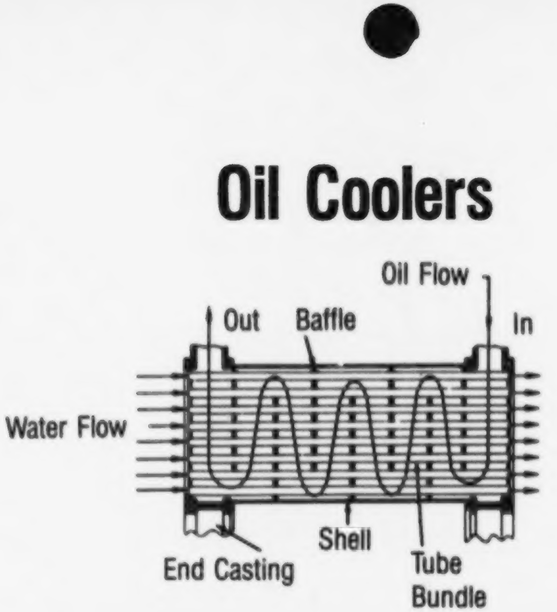
Lubricating Valves



1 Oil Pan
2 Screen — Oil Pump Intake
3 Oil Pump
4 Valve — Pressure Relief
5 Oil Filter
6 Oil Cooler
7 Oil Manifold in Cylinder Block
8 By-pass Filter
9 By-pass Valve — Cooler
10 Cooler By-pass (in the cooler adapter)
11 Vertical passage to upper Cylinder Block and Head
12 Passage to Main Bearings
13 Pressure Regulator Valve

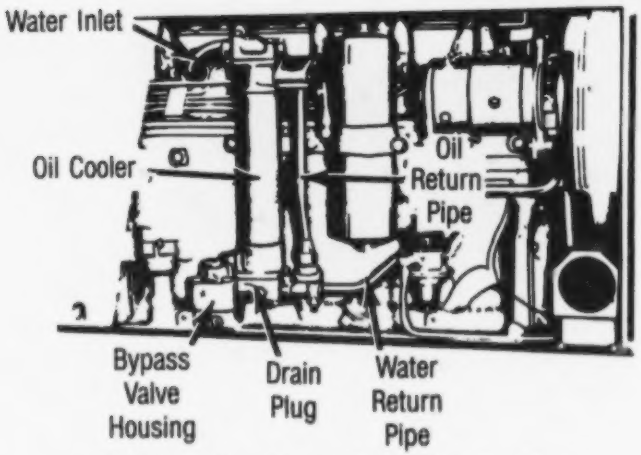
(Courtesy of Detroit Diesel Corporation.)

Oil Coolers

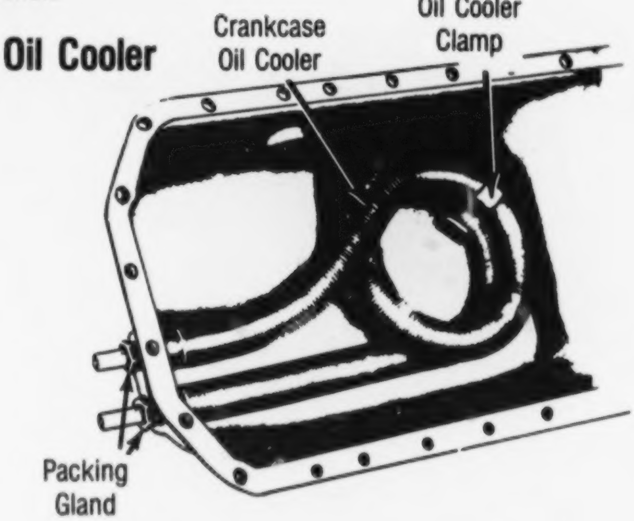

Oil Flow
Out
Baffle
In
Water Flow
Shell
End Casting
Tube Bundle

(Courtesy of Detroit Diesel Corporation.)

Operation of Engine Oil Cooler

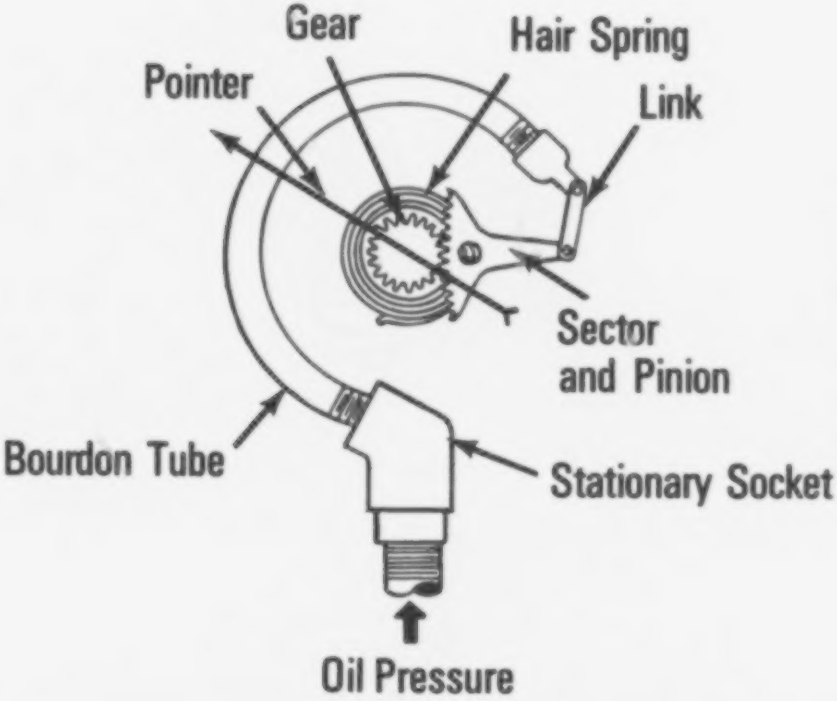

Water Inlet
Oil Cooler
Oil Return Pipe
Bypass Valve Housing
Drain Plug
Water Return Pipe

Externally Mounted Oil Cooler

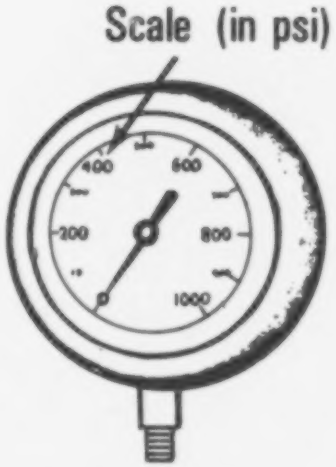

Crankcase Oil Cooler
Oil Cooler Clamp
Packing Gland

Internally Mounted Oil Cooler

Mechanical Oil Pressure Indicating System


Gear
Hair Spring
Pointer
Link
Sector and Pinion
Bourdon Tube
Stationary Socket
Oil Pressure

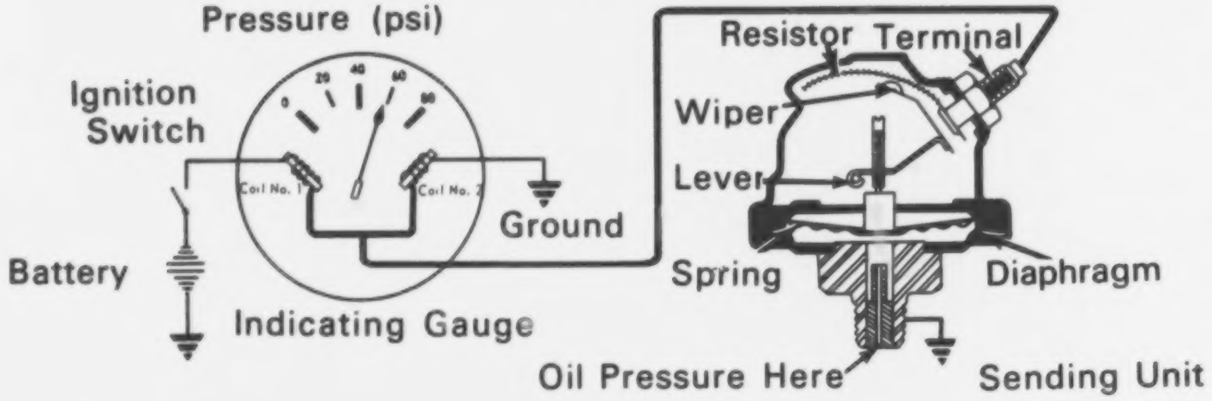
Bourdon Tube Oil Gauge


Scale (in psi)
400
600
200
800
0
1000

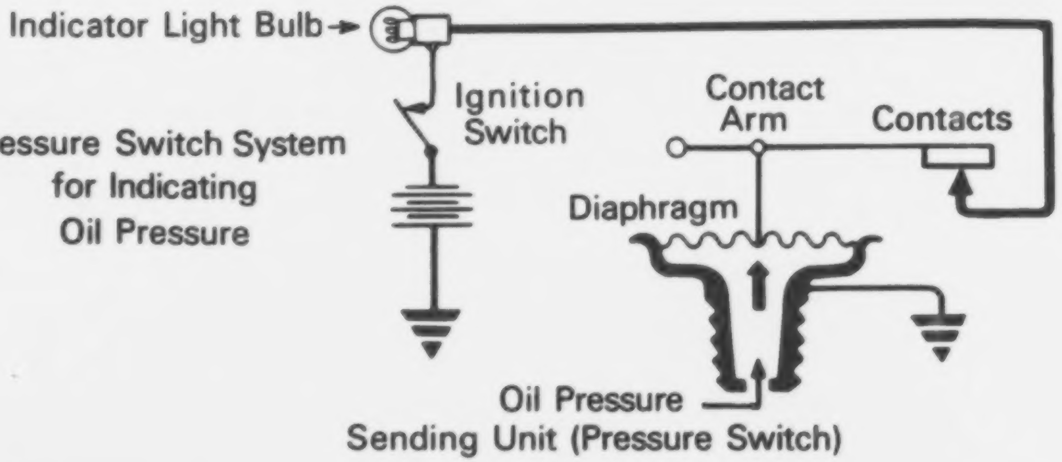
Complete Gauge

Electrical Oil Pressure Indicating Systems

Electromagnetic Coil System for Indicating Oil Pressure


Pressure (psi)
0
20
40
60
80
Ignition Switch
Battery
Coil No. 1
Coil No. 2
Ground
Indicating Gauge
Resistor
Terminal
Wiper
Lever
Spring
Diaphragm
Oil Pressure Here
Sending Unit

Pressure Switch System for Indicating Oil Pressure


Indicator Light Bulb
Ignition Switch
Contact Arm
Contacts
Diaphragm
Oil Pressure
Sending Unit (Pressure Switch)

LUBRICANTS AND LUBRICATING SYSTEMS
UNIT I-C

HANDOUT #1 — API ENGINE OIL CLASSIFICATION

SA (OLD CLASSIFICATION ML) Used under such mild conditions that the protection afforded by compounded oils is not required. (Gasoline and diesel)

SB (OLD CLASSIFICATION MM) Provides only antiscuff capability, and resistance to oil oxidation, and bearing corrosion. (Minimum duty gasoline)

SC (OLD CLASSIFICATION MS) Provides control of high- and low-temperature deposits, wear, rust, and corrosion. (Gasoline)

SD (OLD CLASSIFICATION MS) Gives more protection against high- and low-temperature engine deposits, wear, rust, and corrosion than SC classification. (Gasoline)

SE (NO OLD CLASSIFICATION) Provides more protection against oil oxidation deposits, high-temperature engine deposits, rust, and corrosion than SD or SC classification oils. (Gasoline, 1972 models-)

SG (OLD CLASSIFICATION SF, SE, SF/CC or SE/CC) Improves control of engine deposits, oil oxidation, and engine wear. (Gasoline, passenger cars, vans, light duty trucks beginning in 1989.

CA (OLD CLASSIFICATION DG) Provides protection against bearing corrosion and from high-temperature deposits in naturally aspirated diesel engines. (Light duty diesel)

CB (OLD CLASSIFICATION DM) Provides necessary protection from bearing corrosion and from high-temperature deposits in naturally aspirated diesel engines using sulfur fuels. (Moderate duty diesel)

CC (OLD CLASSIFICATION DM) Provides protection from high-temperature deposits in lightly supercharged diesel engines and also from rust, corrosion, and low-temperature deposits in gasoline engines. (Moderate-to-severe-duty diesel and gasoline trucks, farm tractors, construction and industrial equipment)

CD (OLD CLASSIFICATION DS) (SERIES 3 OIL) Provides protection from bearing corrosion and from high-temperature deposits in supercharged engines when utilizing a wide quality range of fuels. (Severe duty diesel)

CDII Used in two-stroke cycle diesel engines requiring highly effective controls over wear and deposits. (Heavy duty trucks and buses, off-highway equipment including construction and stationary equipment)

CE Used in turbocharged or supercharged heavy duty diesel engines. (Diesel, 1983-)

(The API Engine Service Classification Symbol is a registered service mark of the API. It is licensed to engine oil marketers for use on containers of their certified oils which meet or exceed the technical requirements defined by ASTM. The information above was provided courtesy of American Petroleum Institute, 1220 L. Street, Washington, D.C. 20005)

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

JOB SHEET #1 — CHECK OIL PRESSURE ON A LIVE ENGINE

A. Tools and equipment

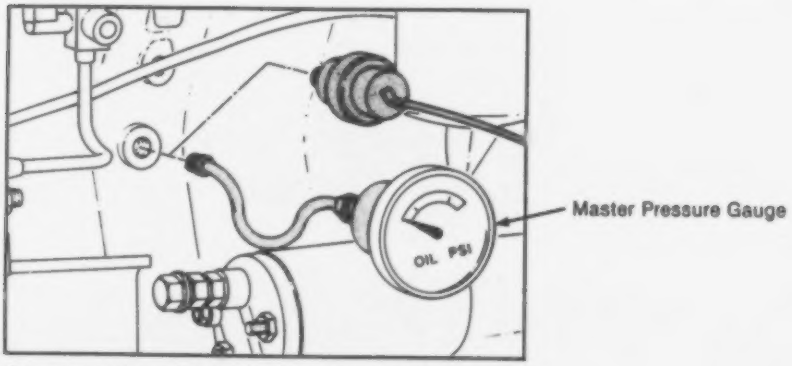
1. Screwdriver
2. Master pressure gauge
3. End wrench
4. Shop towels
5. Safety glasses

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Check condition of oil filter; replace if dirty.
2. Install a master pressure gauge. (Figure 1)

FIGURE 1



(Courtesy of Cummins Engine Company, Inc.)

3. Start engine and warm up at fast idle speed.
4. Record pressure reading on the gauge.
5. Compare reading with the engine specifications.

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

JOB SHEET #2 — CHANGE AN OIL FILTER

A. Tools and equipment

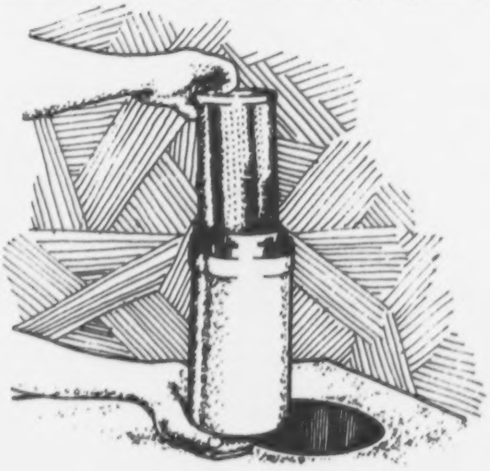
1. Engine
2. Appropriate service manual
3. Shop towels
4. Container to catch waste oil
5. Suitable wrenches to remove oil filter
6. Safety glasses

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Change replaceable, element-type oil filter.
   a. Position drain pan under oil filter.
   b. Remove filter housing drain plug and allow oil to drain.
   (CAUTION: Be careful of hot oil which can seriously burn the skin.)
   c. Remove oil filter housing bolt.
   d. Remove oil filter housing.
   e. Remove oil filter element from filter housing. (Figure 1)

FIGURE 1



JOB SHEET #2

f. Clean the filter housing.

g. Remove old oil filter housing gasket.

h. Install new oil filter housing gasket.

(NOTE: Make sure the new gasket is placed correctly.)

i. Install new oil filter element in filter housing.

j. Install oil filter housing and tighten bolt securely.

k. Add oil or refill crankcase as required.

l. Start engine.

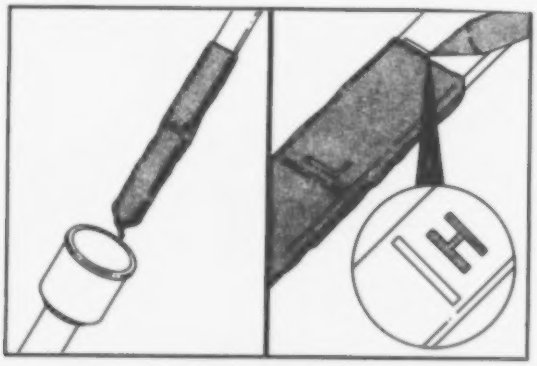
m. Check for leaks.

n. Shut off engine.

o. Check oil level on dipstick. (Figure 2)

(NOTE: When changing oil refill to correct capacity, and check dipstick for accuracy.)

FIGURE 2



(Courtesy of Cummins Engine Company, Inc.)

p. Make out service sticker indicating date and mileage oil filter was changed.

2. Change sealed, cartridge-type oil filter.

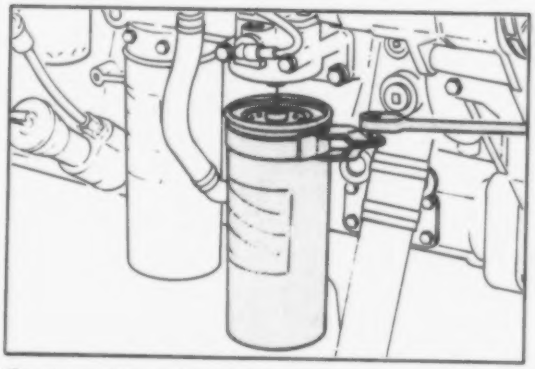
a. Place drain pan under oil filter.

b. Remove oil filter cartridge with suitable tool. (Figure 3)

(NOTE: Turn counterclockwise to remove.)

JOB SHEET #2

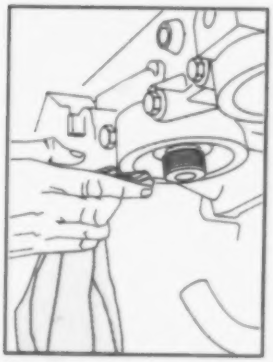
FIGURE 3



(Courtesy of Cummins Engine Company, Inc.)

c. Clean the oil filter head surface. (Figure 4)

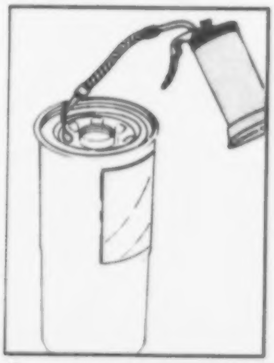
FIGURE 4



(Courtesy of Cummins Engine Company, Inc.)

d. Lubricate the sealing gasket on the new oil filter cartridge with clean motor oil. (Figure 5)

FIGURE 5



(Courtesy of Cummins Engine Company, Inc.)

JOB SHEET #2

e. Fill the filters with clean motor oil.

f. Install the filters on the oil filter head and tighten the filters until the gasket contacts the filter head surface.

g. Use an oil filter wrench to tighten the filters an additional three-fourths to one turn, or follow the instructions supplied with the filters.

h. Operate the engine and check for leaks.

i. Shut off engine and check oil level.

j. Make out service sticker indicating date and mileage oil filter was changed.

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

PRACTICAL TEST
JOB SHEET #1 — CHECK OIL PRESSURE ON A LIVE ENGINE

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked oil filter.	______	______
3. Installed master gauge.	______	______
4. Started engine.	______	______
5. Recorded pressure reading.	______	______
6. Compared reading with specifications.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Student's evaluation of engine oil pressure is correct.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

PRACTICAL TEST
JOB SHEET #2 — CHANGE AN OIL FILTER

STUDENT'S NAME ____________________ DATE __________

EVALUATOR'S NAME ____________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	____	____
2. Positioned drain under filter.	____	____
3. Drained oil filter.	____	____
4. Removed filter.	____	____
5. Cleaned all components.	____	____
6. Installed new filter.	____	____
7. Added oil.	____	____
8. Started engine and checked for leaks.	____	____
9. Made out service sticker.	____	____
10. Checked in/put away tools and materials.	____	____
11. Cleaned the work area.	____	____
12. Used proper tools correctly.	____	____
13. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	____	____
14. Practiced safety rules throughout procedure.	____	____
15. Provided satisfactory responses to questions asked.	____	____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Filter is installed correctly with no leaks.				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

LUBRICANTS AND LUBRICATING SYSTEMS
UNIT I-C

NAME ______________________ SCORE ____________________

TEST

1. Match terms related to lubrication systems with the correct definitions.

______a. Certain properties added to oil to provide extra performance

______b. Oils compounded to behave as light oils at cold temperatures and heavy oils at warm temperatures

______c. Society of Automotive Engineers

______d. American Petroleum Institute

______e. Oil specifications prepared by the Ordinance Department of the Military Forces

______f. American Society for Testing Materials

______g. A measure of the fluidity of an oil at a given temperature

______h. Instrument used to measure the length of time in seconds required for a specified volume of oil to flow through a small orifice when the oil is brought to a specified temperature

______i. Resistance to movement between any two objects placed in contact with each other

______j. Pipe or passageway in the engine used to carry engine oil from one area to another

1. Additives
2. API
3. ASTM
4. Friction
5. Gallery
6. MIL
7. Multi-grade oil
8. SAE
9. Viscometer
10. Viscosity

2. Select the statements concerning characteristics of a good engine oil by placing an "X" beside the correct statement(s).

______a. Keeps a protective film on moving parts

______b. Resists breakdown at high temperatures

______c. Resists corrosion and rusting

TEST

_____d. Prevents carbon buildup

_____e. Prevents sludge formation

_____f. Flows easily at low temperatures

_____g. Flows easily at high temperatures

_____h. Resists foaming

_____i. Resists breakdown after long use

3. Complete the list of statements explaining SAE viscosity number by inserting the correct word(s) that best completes the sentence.

   Example: Oils vary in *viscosity* as temperatures change.

   a. Lighter oils for winter use are specified at 0°F and carry a ________ symbol.

   b. Heavier oils are specified at 210°F and carry a ________ viscosity number.

4. Select true statements concerning the API classification system by placing an "X" beside each statement that is true.

_____a. Joint effort of API, ASTM, and SAE organizations

_____b. Attempts to clarify oil specifications and oil qualities between the engine manufacturer, the petroleum industry, and the customer

5. Select true statements concerning engine oil by placing an "X" beside each statement that is true.

_____a. Oil becomes unfit for further use as it absorbs contaminants and as additives are depleted.

_____b. Multi-viscosity oils are not always preferred.

_____c. Black oil does not mean time for an oil change.

_____d. Buy quality oil filters as recommended by machine operator's manual.

_____e. Oil oxidation results in thicker oil.

_____f. Using a light oil until consumption increases, and then switching to a heavier oil, is not a good practice.

_____g. Following operator's manual recommendations is critical to insure good performance.

TEST

6. List five general rules for selection and use of oils for best engine performance.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

7. Complete statements concerning common sources of oil contamination by filling in the blanks correctly with the following words: oil, dust, handling, warm-up, fuel, engine.

   a. Storing and ____________

   b. ____________ from air that is breathed into engine

   c. Improper engine ____________

   d. Antifreeze leaking into ____________ supply

   e. ____________ wear

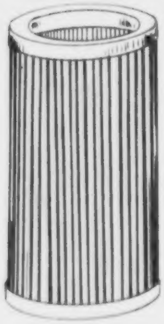
   f. ____________ dilution

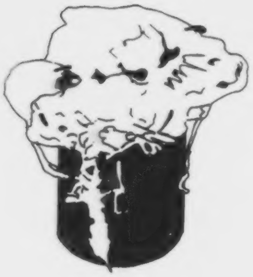
8. Match the diagnostic tests related to oil analysis with the correct descriptions.

_____a.	Detects component wear and dust contamination	1. Chemical and physical tests
_____b.	Detect water, fuel, and antifreeze	2. Oil condition analysis
_____c.	Detects soot, sulfur, oxidation and nitration products	3. Wear analysis

TEST

9. Identify two types of oil filters.





a. ________________ b. ________________

10. List five functions of the lubrication system.

a. ________________

b. ________________

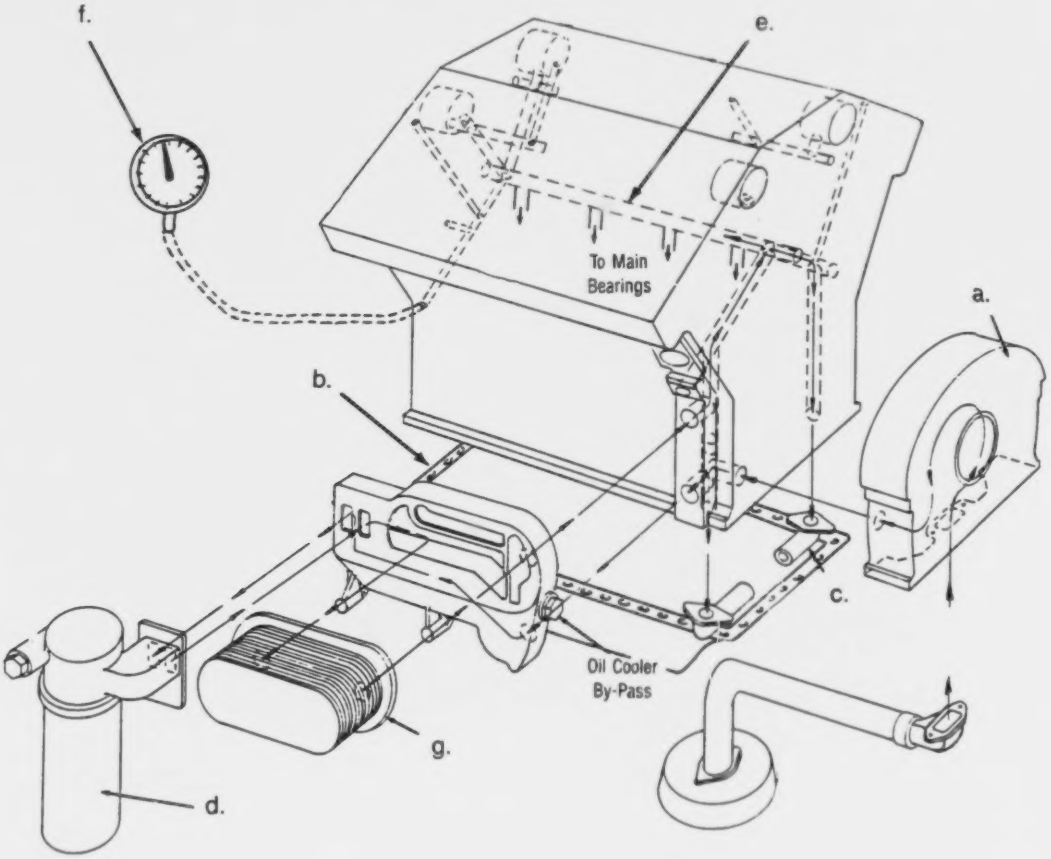
c. ________________

d. ________________

e. ________________

TEST

11. Identify the components of the lubrication system.


f.
e.
To Main Bearings
a.
b.
c.
Oil Cooler By-Pass
g.
d.

a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________

TEST

12. Match the components related to lubrication systems with the purposes.

_____a. Provides a reservoir for the engine oil

_____b. Limits the maximum oil pressure

_____c. Carry engine oil from one area to another

_____d. Indicates oil pressure during engine operation

_____e. Forces oil under pressure to various parts of the engine for lubrication

_____f. Strains the engine oil by removing abrasive particles

_____g. Engine coolant flows through the unit and helps dissipate the heat in the engine oil

1. Oil cooler
2. Oil filter
3. Oil galleries
4. Oil pan
5. Oil pump
6. Pressure gauge
7. Pressure regulating valve

13. Match the lubricating valves with the purposes.

_____a. Bypasses excess oil when the engine is cold or when the pressure exceeds approximately 100 PSI

_____b. Limits oil gallery pressure to about 45 to 50 PSI

_____c. Bypasses lubricating components when they become restricted

_____d. Prevents oil from draining from the filter when the engine is stopped

1. Antidrain check valve
2. By-pass valve
3. Pressure relief valve
4. Pressure regulator valve

14. Name two types of oil pumps.

a. ____

b. ____

15. Distinguish between internally and externally mounted oil coolers by placing an "X" next to the description of circulation in an internally mounted oil cooler.

_____a. Both water and oil are pumped through the oil cooler.

_____b. Engine coolant is pumped by water pump through oil cooler mounted in the crankcase and back to the radiator where the heat is dissipated.

TEST

16. Select true statements concerning mechanical and electrical oil pressure indicating systems by placing an "X" beside the true statement(s).

______a. Mechanical-Bourdon tube gauge which tends to straighten out when pressure is applied

______b. Electrical

17. Select true statements concerning oil temperature indicating system by placing an "X" beside the true statement(s).

______a. Electromagnetic gauge is mounted in control panel

______b. Variable resistor sending unit is mounted in the cylinder head

18. Match terms related to components of an oil pressure shutdown or alarm circuit with the correct definitions.

______a. A combination gauge and switch for alarm or shutdown or equipment

______b. Grounds magnetors; energizes relays and actuates valves

______c. Opens or closes when current is supplied, cutting off fuel to engine

1. Fuel shutoff valve
2. Magnetic switch
3. Swichgage®

19. Arrange in order the steps of operation of the oil pressure shutdown or alarm circuit by placing the correct sequence number in the appropriate blank.

______a. If oil pressure drops during operation the pointer of the gauge contacts the low oil pressure adjustment screw, grounding the Swichgage®.

______b. A fuel valve holding coil is wired through the magnetic switch.

______c. Grounding the Swichgage® causes the magnetic switch to open the circuit to the fuel shutoff solenoid at the injection pump.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

    a. Check oil pressure on a live engine. (Job Sheet #1)

    b. Change an oil filter. (Job Sheet #2)

LUBRICANTS AND LUBRICATION SYSTEMS
UNIT I-C

ANSWERS TO TEST

1.

a.	1	f.	3
b.	7	g.	10
c.	8	h.	9
d.	2	i.	4
e.	6	j.	5

2. a, b, c, d, e, f, h, i

3. a. 5W, 10W, or 20W
   b. 20, 30, 40, or 50

4. a, b

5. a, b, c, d, e, f, g

6. Any five of the following:
   a. Use brands which meet engine manufacturer's specifications.
   b. Drain and change at recommended intervals.
   c. Select oils which have been performance tested.
   d. Never mix oils of various MIL specifications.
   e. Bring engine up to normal operating temperature each time it is used.
   f. Keep oil containers covered, sealed, and protected to prevent contamination.

7. a. Handling
   b. Dust
   c. Warm-up
   d. Oil
   e. Engine
   f. Fuel

8. a. 3
   b. 1
   c. 2

9. a. Depth filter
   b. Surface filter

ANSWERS TO TEST

10. a. Reduces friction between moving parts
    b. Absorbs and dissipates heat
    c. Seals the piston rings and cylinder walls
    d. Cleans and flushes moving parts
    e. Helps deaden the noise of the engine by absorbing shock

11. a. Oil pump
    b. Oil pan
    c. Pressure regulating valve
    d. Oil filter
    e. Oil galleries
    f. Pressure gauge
    g. Oil cooler

12. a. 4
    b. 7
    c. 3
    d. 6
    e. 5
    f. 2
    g. 1

13. a. 3
    b. 4
    c. 2
    d. 1

14. a. Gear
    b. Rotor

15. b

16. a, b

17. a

18. a. 3
    b. 2
    c. 1

19. a. 2
    b. 1
    c. 3

20. Performance skills evaluated to the satisfaction of the instructor

COOLANTS AND COOLING SYSTEMS
UNIT II-C

UNIT OBJECTIVE

After completion of this unit, the student should be able to test for combustion leakage and air in the cooling system. The student should also be able to clean the cooling system. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to coolants and cooling systems with the correct definitions.
2. Name types of cooling systems used on modern engines.
3. Match the parts of a cooling system with the correct functions.
4. Complete statements concerning the parts of an air cooled engine and their functions.
5. List requirements of a good antifreeze.
6. List preventive maintenance procedures for maintaining a cooling system.
7. Name functions of the cooling system.
8. List effects of an engine running too hot.
9. List effects of an engine running too cold.
10. Identify parts in a liquid cooling system.

OBJECTIVE SHEET

11. Identify types of radiators.
12. Name functions of the radiator cap.
13. Identify types of fans used in cooling systems.
14. Name types of fan controls.
15. Name types of temperature gauges.
16. List purposes for using a coolant filter or conditioner in the cooling system.
17. Select functions of the thermostat.
18. Identify types of thermostats.
19. Select common materials that may restrict radiator coolant flow.
20. Identify primary parts of a water pump.
21. Demonstrate the ability to:
    a. Test for combustion leakage into the cooling system. (Job Sheet #1)
    b. Test for air in cooling system. (Job Sheet #2)
    c. Clean the cooling system. (Job Sheet #3)

COOLANT AND COOLING SYSTEMS
UNIT II-C

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Have students trace coolant flow through their engine.
   2. Have students define electrolysis.
   3. Demonstrate and discuss the procedures for measuring specific gravity in a cooling system.
   4. Discuss cooling system conditioners.
   5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Service Bulletin No. 3810245-00, NT 855 Cooling Systems.* Columbus, IN: Cummins Engine Company, Inc., 1985.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

C. Schulz, Erich V. *Diesel Mechanics.* 2nd ed. Dallas: McGraw-Hill Book Company, 1983.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Filmstrips:

1. *Basic Cooling Systems* (40 slides and script)
   Order #SESV1031
   Caterpillar Inc., Literature Order Section
   P.O. Box 5319
   Morton, IL 61550

2. *Troubleshoooting Cooling Systems* (48 slides and script)
   Order #SESV1352
   Caterpillar Inc., Literature Order Section
   P.O. Box 5319
   Morton, IL 61550

COOLANTS AND COOLING SYSTEMS
UNIT II-C

INFORMATION SHEET

I. **Terms and definitions**

A. Aeration — Mixture of air and water

B. Antifreeze — Material added to coolant to prevent freezing

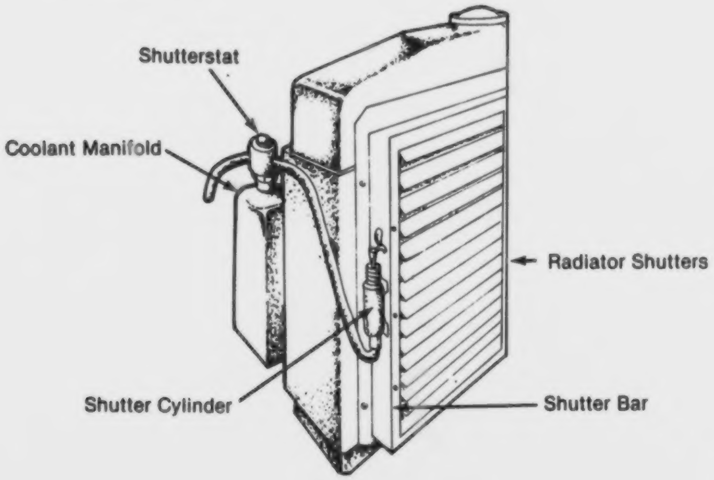
C. Bimetallic — Two strips of dissimilar metal welded together, one of which expands more when heated than the other

D. Coolant — Liquid that absorbs and transfers heat to maintain normal engine operating temperature

E. Inhibiter — Chemical which dissolves in water to form a rustproof film on the metal

F. Permanent antifreeze — Liquid solution which contains properties that will not readily boil away

G. Radiator shutters — Device over radiator to maintain temperature variations of coolant



II. **Types of cooling systems used on modern engines**

A. Air

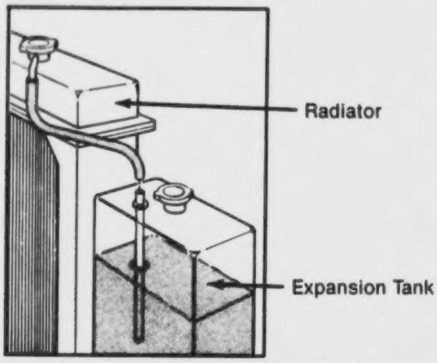
B. Liquid

INFORMATION SHEET

III. **Parts of a liquid cooling system and the functions** (Transparencies 1 and 2)

A. Radiator — Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine

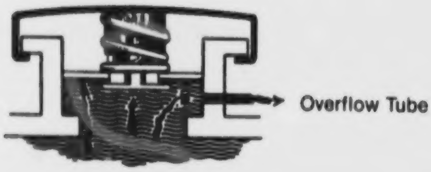
B. Expansion tank — Separate tank in cooling system that allows for heat expansion of coolant



(Courtesy of Cummins Engine Company, Inc.)

C. Pressure cap — Relieves pressure from too much heat; lets in air pressure as liquid cools

(NOTE: A pressurized cooling system raises the boiling temperatures of coolants about 2° for each pound of pressure.)



D. Fan — Forces cooling air through radiator core to more quickly dissipate heat

E. Fan belt — Transmits power from engine crankshaft to drive fan and water pump

F. Water pump — Circulates coolant through the system

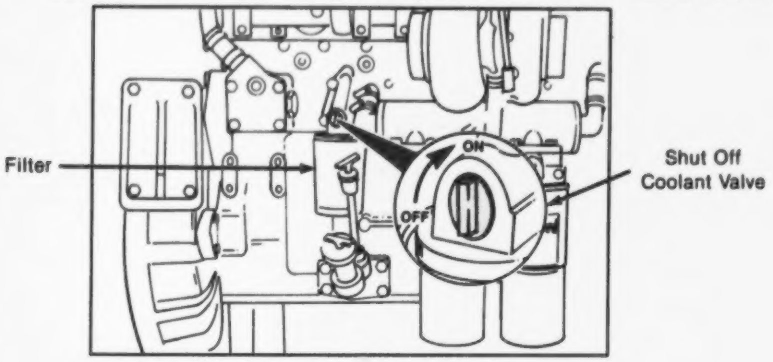
G. Thermostat — Controls the flow of coolant to radiator to maintain correct operating temperatures

H. Hoses — Flexible connections between engine and other parts of cooling system

INFORMATION SHEET

I. Coolant — Medium which carries away excess heat from engine

J. Coolant filter — Used in some engines to soften the water and remove dirt



(Courtesy of Cummins Engine Company, Inc.)

IV. **Parts of an air cooled engine and their functions** (Transparency 1)

A. Direct cooling system — Forces air by the cylinders at all times while engine is running

B. Fin head and cylinder blocks — Allow cool air to go by the head and cylinders to draw heat away

C. Aerodynamic intake port — Brings air into chambers in a swirling motion for more efficient combustion process

V. **Requirements of a good antifreeze**

A. Prevents freezing

B. Inhibits rust and corrosion

C. Chemically stable

D. Nonconductor of electricity

E. Flows readily at all temperatures

F. Conducts heat readily

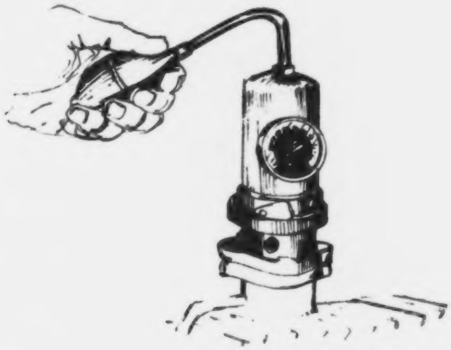
G. Resists foaming

INFORMATION SHEET

VI. **Preventive maintenance procedures**

A. Inspect for system deterioration.

(NOTE: Pressure test the cooling system.)



B. Prevent corrosion and deposits.

C. Flush and clean system periodically.

D. Allow a hot engine to idle a few minutes before shutting it down.

(NOTE: Idle speed allows temperatures of parts to equalize and prevents after boil of coolant.)

E. Check coolant as recommended in operator's manual.

VII. **Functions of the cooling system**

A. Prevents engine overheating

B. Regulates engine temperature

VIII. **Effects of an engine running too hot**

A. Excessive wear

B. Scoring

C. Knock

D. Burned piston and valves

INFORMATION SHEET

E. Lubrication failure

F. Seizure of moving parts

G. Loss of power

IX. Effects of an engine running too cold

A. Excessive wear

B. Poor fuel economy

C. Accumulation of water and sludge in the crankcase

D. Loss of power

X. Parts in a liquid cooling system (Transparency 2)

A. Water pump

B. Oil cooler

C. Water manifold

D. Temperature sending unit

E. Aftercooler

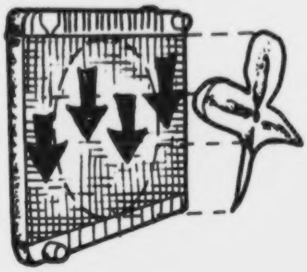
F. Thermostat

G. Bypass

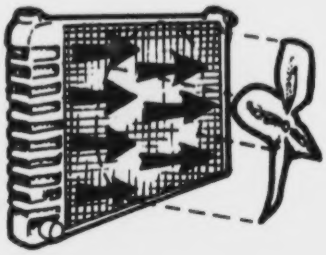
H. Engine water jacket

XI. Types of radiators

A. Down-flow

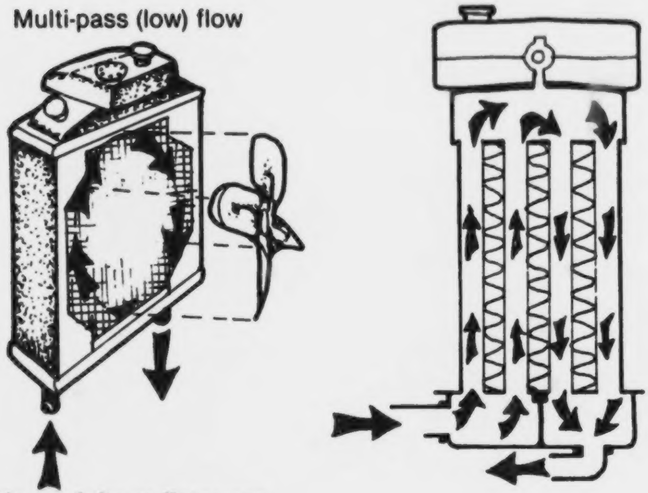


B. Cross-flow



INFORMATION SHEET

C. Multi-pass (low) flow

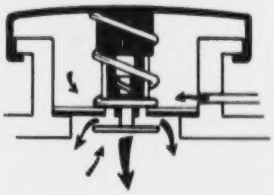


XII. **Functions of the radiator cap**

(NOTE: There are different ratings of pressure caps.)

A. Allows atmospheric pressure to enter the cooling system

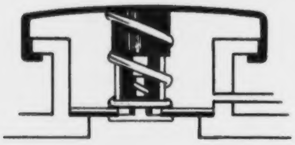
(NOTE: The vacuum valve opens.)



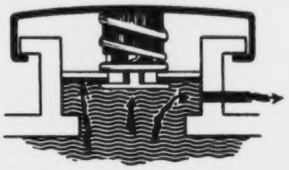
Vacuum Valve Open

B. Prevents coolant from escaping at normal temperatures

(NOTE: The pressure valve permits escape of coolant or steam when pressure reaches a certain point. Pressure rise of one pound will raise the boiling temperature of water about 3 degrees fahrenheit.)



Valves Closed

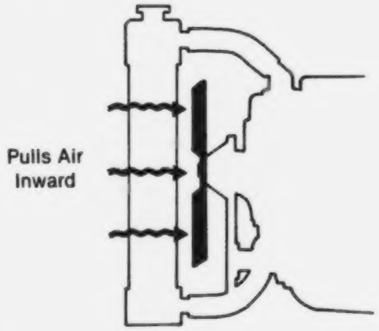


Pressure Valve Open

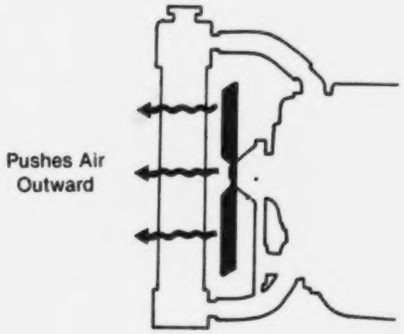
INFORMATION SHEET

XIII. Types of fans used in cooling systems

A. Suction


Pulls Air
Inward

B. Blower


Pushes Air
Outward

XIV. Types of fan controls (Transparency 3)

A. Clutch

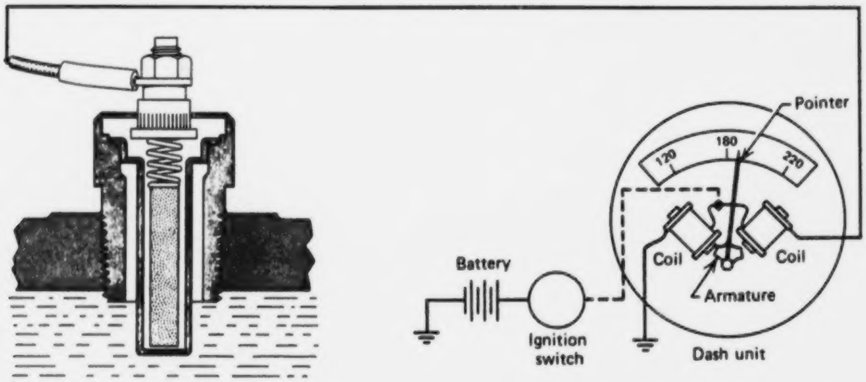
B. Viscous

C. Air operated

D. Electric

XV. Types of temperature gauges

A. Electrical

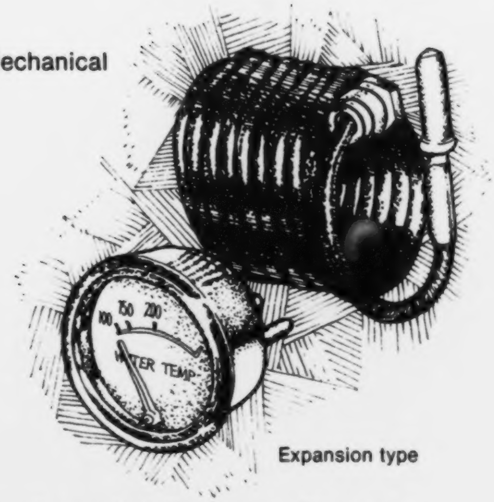

Pointer
120
180
220
Coil
Coil
Armature
Battery
Ignition
switch
Dash unit

Sensing unit rests in coolant and reacts to temperature changes

Dial of temperature gauge records changes in coolant temperature

INFORMATION SHEET

B. Mechanical



Expansion type

XVI. Purposes of a coolant filter or conditioner

A. Softens the water

(NOTE: Chemicals in the filter element remove corrosives and keep the water jackets free of scale.)

B. Removes dirt

(NOTE: Filter element is replaceable and dirt which settles to bottom may be drained.)

C. Provides a place for rust inhibitors in the filter element.

(NOTE: Rust inhibitors dissolve to form a rust proof film on the metal surfaces of the cooling system.)

XVII. Functions of the thermostat (Transparency 4)

A. Provides automatic control of the engine temperature

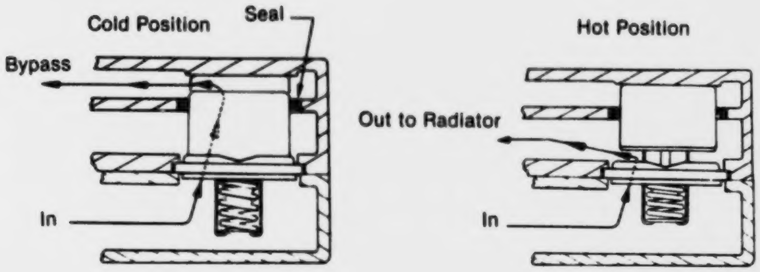
B. Permits rapid engine warm-up when closed

C. Permits efficient cooling when open

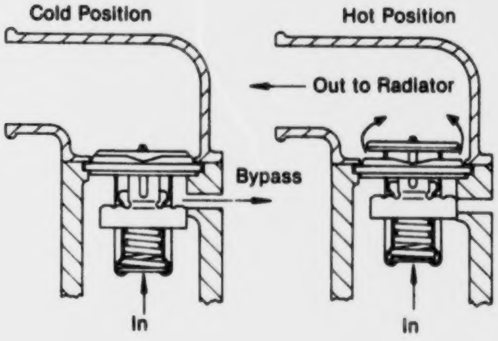
INFORMATION SHEET

XVIII. Types of thermostats

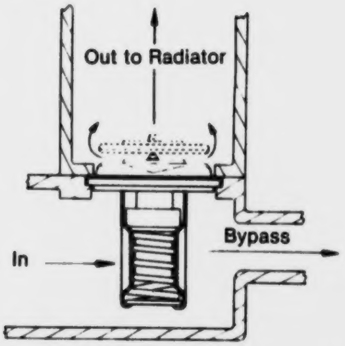
A. Full blocking


Cold Position
Seal
Bypass
In
Hot Position
Out to Radiator
In

B. Non-blocking


Cold Position
Hot Position
Out to Radiator
Bypass
In
In

C. Partial blocking


Out to Radiator
In
Bypass

(Illustrations A, B, and C courtesy of Detroit Diesel Corporation.)

INFORMATION SHEET

XIX. **Materials that may restrict radiator coolant flow**

A. Rust

B. Scale

C. Oil

D. Lime

E. Silicate jelly

(NOTE: If an antifreeze solution is overconcentrated and/or large amounts of corrosion inhibitor supplements are used, the excess silicate will "drop out" of the coolant, and silica gel will build up in the cooling systems.)

XX. **Primary parts of a water pump** (Transparency 5)

A. Fan hub

B. Pulley

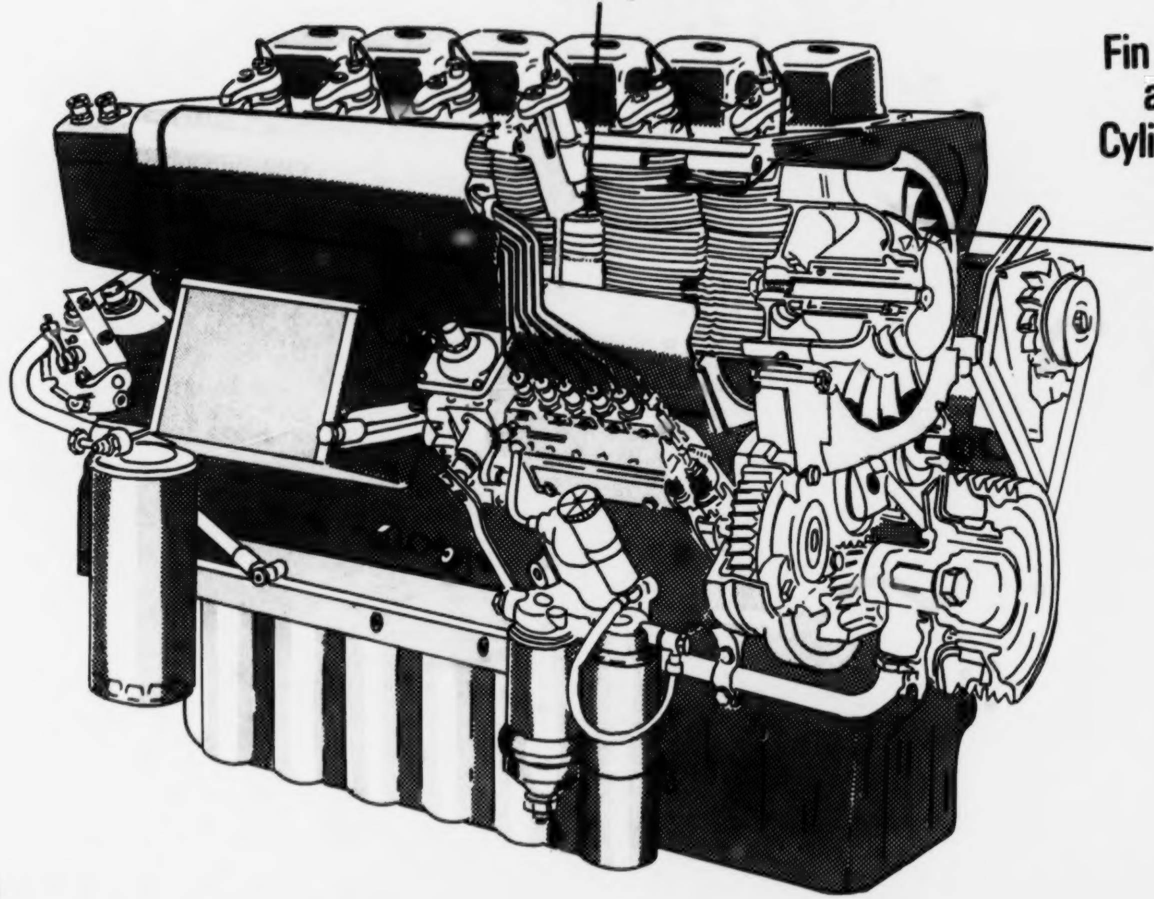
C. Bearing and shaft assembly

D. Water pump housing

E. Impeller

F. Weep hole

Air Cooled Diesel Engine

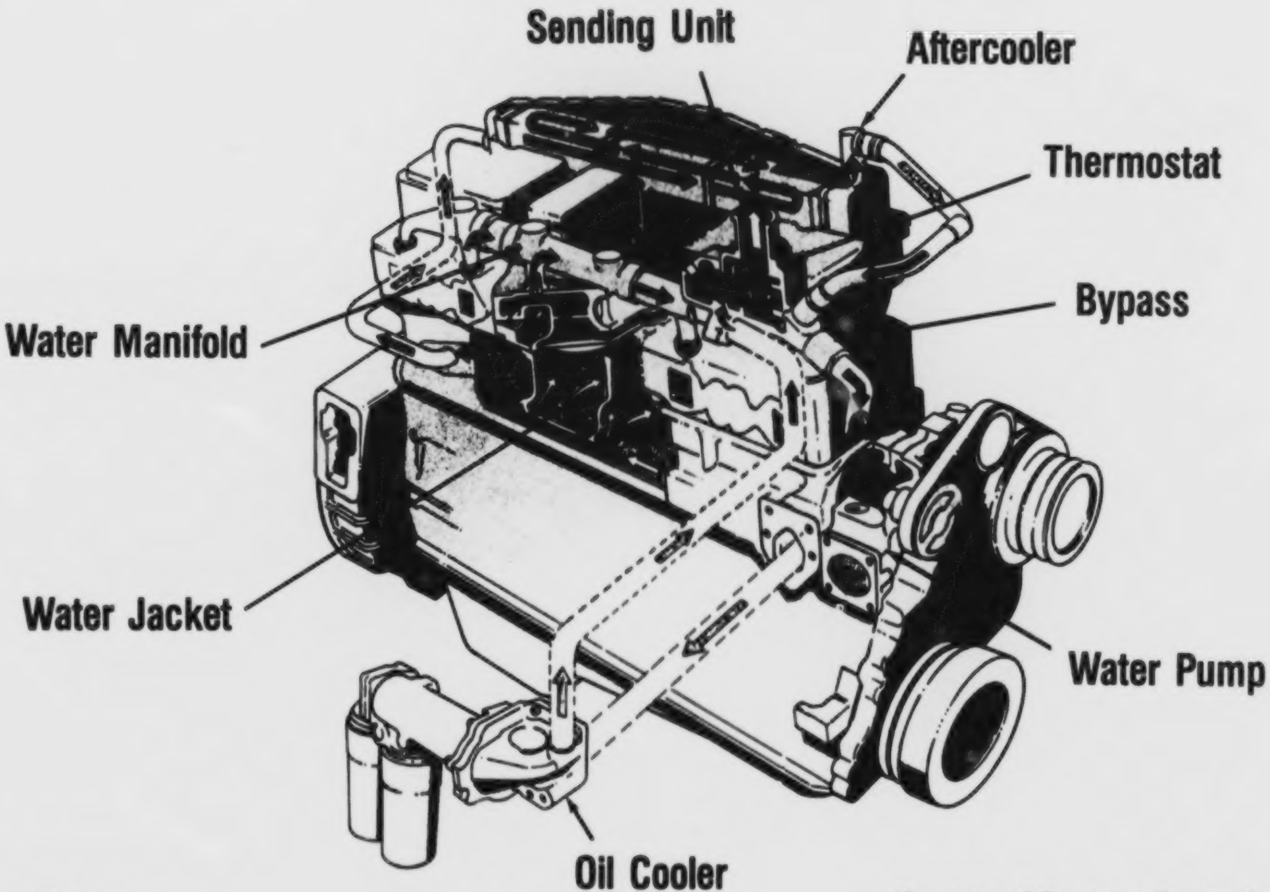


Aerodynamic Intake Port

Fin Head
and
Cylinder Block

Direct
Cooling
System

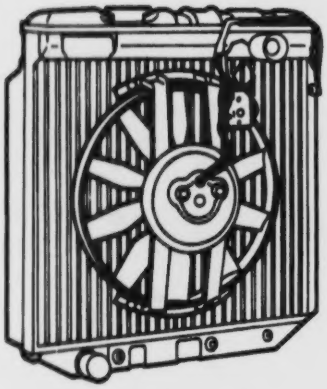
Liquid Cooling System



Sending Unit
Aftercooler
Thermostat
Bypass
Water Manifold
Water Jacket
Water Pump
Oil Cooler

(Courtesy of Cummins Engine Company, Inc.)

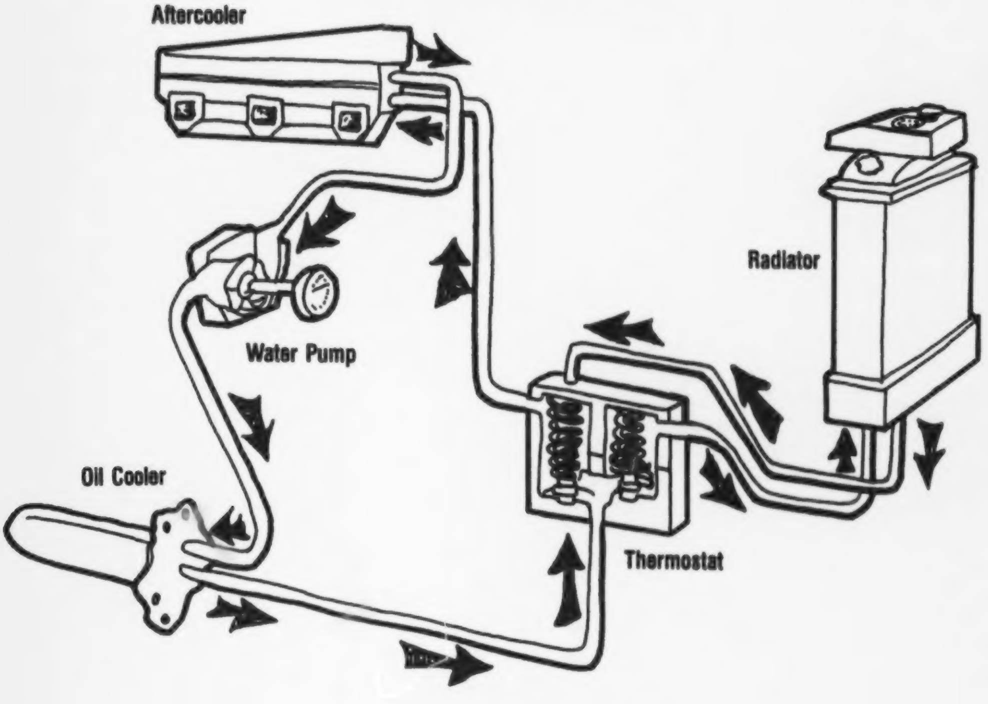
Fan Controls



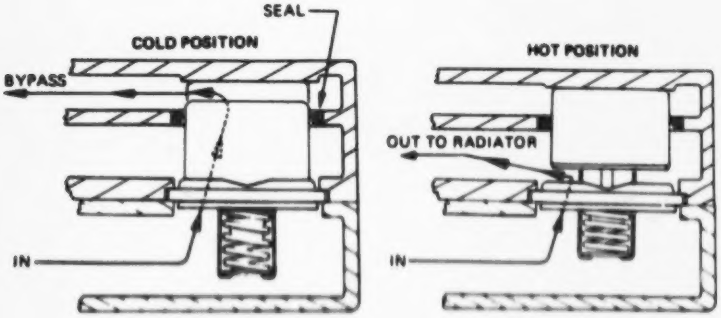
Electric Fan

(R.L. Little and G.C. Edmondson, *DIESEL MECHANICS: AN INTRODUCTION*. Copyright 1982 PWS-KENT Publishing Company, a division of Wadsworth, Inc.)

Thermostats


Aftercooler
Radiator
Water Pump
Oil Cooler
Thermostat

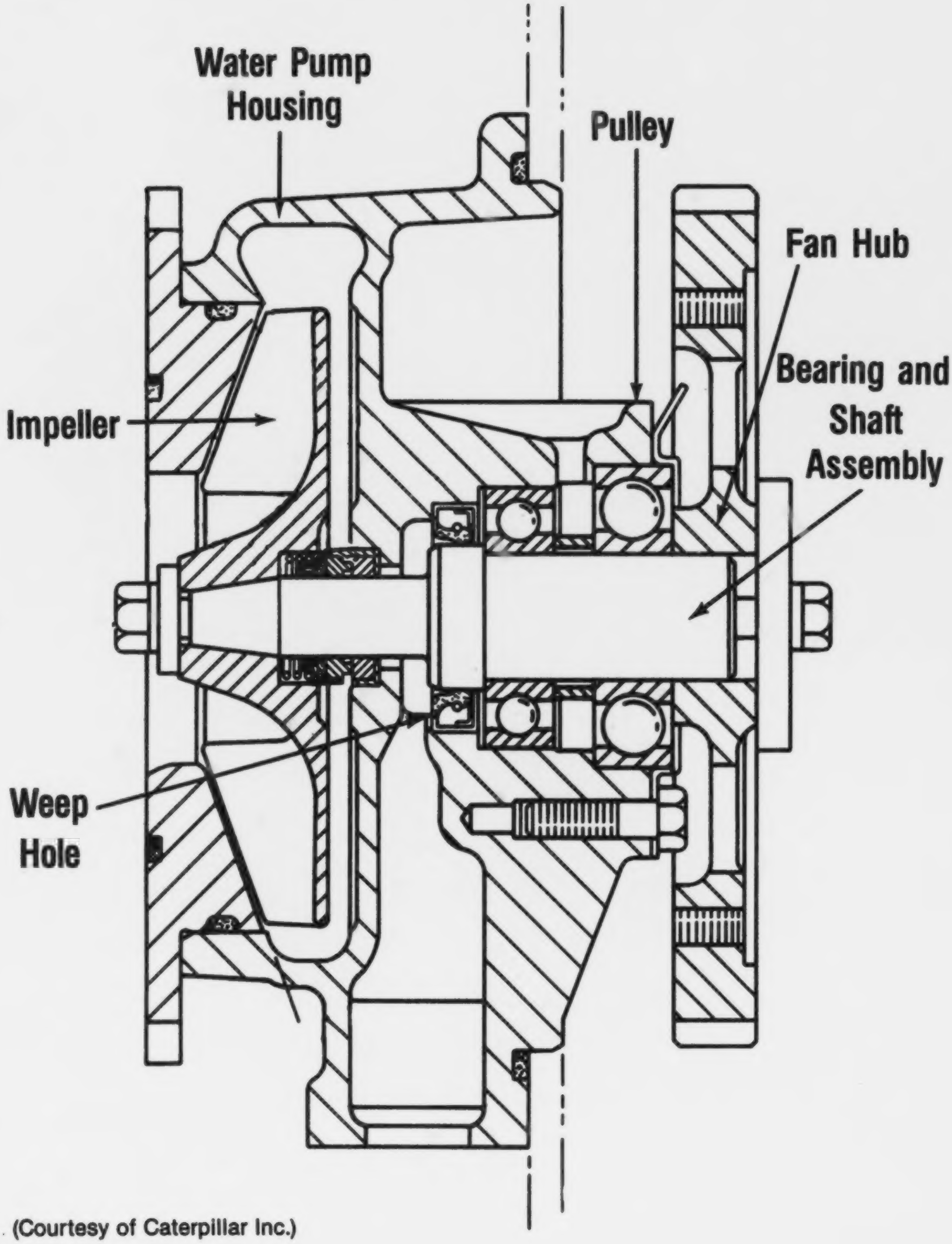
Coolant Flow


SEAL
COLD POSITION
BYPASS
IN
HOT POSITION
OUT TO RADIATOR
IN

Full Blocking Type Thermostat

(Courtesy of Detroit Diesel Corporation.)

Parts of a Water Pump


Water Pump
Housing
Pulley
Fan Hub
Bearing and
Shaft
Assembly
Impeller
Weep
Hole

(Courtesy of Caterpillar Inc.)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

JOB SHEET #1 — TEST FOR COMBUSTION LEAKAGE INTO COOLING SYSTEM

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Live engine

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Operate the engine until it reaches operating temperature.
2. Drain enough coolant to allow removal of the upper hose and thermostat.
3. Remove the thermostat, upper radiator hose, and drive belts.
4. Refill system with coolant until it reaches the level of the thermostat-housing neck.
5. Start engine and accelerate five to six times.
6. Watch the outlet opening for bubbles or a rise of liquid.

   (NOTE: Appearance of bubbles or a rise of liquid indicates that combustion gases are entering the cooling system)

   (CAUTION: Perform the test as quickly as possible; otherwise the coolant will boil and steam, and bubbles will rise from the thermostat neck causing misleading test results.)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

JOB SHEET #2 — TEST FOR AIR IN COOLING SYSTEM

A. Tools and materials

1. Safety glasses
2. Shop towels
3. Basic hand tools
4. Appropriate service manual
5. Live engine
6. Transparent plastic tube

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: There are two methods used to check for air circulating within the cooling system. One method is to pressure test the cooling system as previously outlined in Unit III-A.)

1. Drain enough coolant from the system to remove top radiator hose from thermostat housing and radiator top tank.
2. Place a transparent plastic tube between the thermostat housing and radiator top tank.
3. Refill the system and start the engine.
4. Run engine until it reaches normal operating temperature.
5. Observe the coolant flow.
6. Check for white round particles passing out of the cylinder head into the radiator through the plastic hose.

COOLANTS AND COOLING SYSTEMS
UNIT II-C

JOB SHEET #3 — CLEAN THE COOLING SYSTEM

A. Tools and materials

1. Live engine
2. Basic hand tools
3. Sodium carbonate
4. Shop towels
5. Safety glasses
6. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

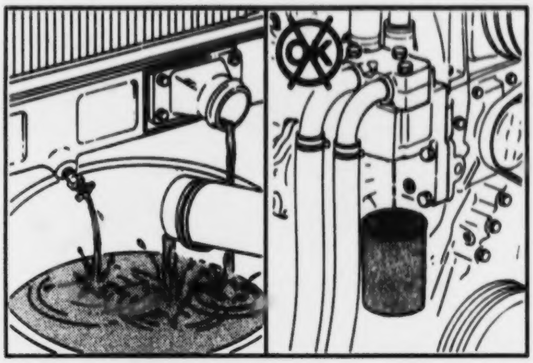
1. Remove the radiator cap after the engine has cooled.

   (CAUTION: Wait until the coolant temperature is below 160°F before removing the radiator cap.)

2. Open the radiator draincock and remove the lower radiator hose and drain cooling system. (Figure 1)

   (NOTE: Do not remove the coolant filters.)

   FIGURE 1



3. Install bottom radiator hose and close draincock.

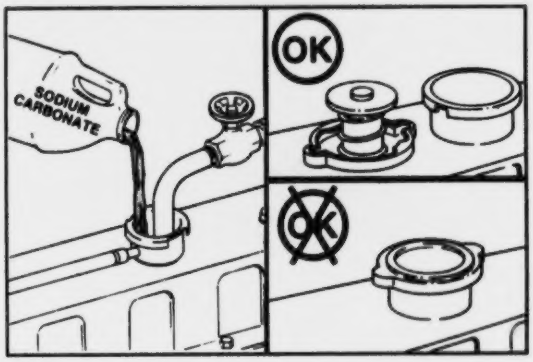
(Figures 1-5 provided courtesy of Cummins Engine Company, Inc.)

JOB SHEET #3

4. Fill the system with a mixture of sodium carbonate and water, or a commercially available equivalent. (Figure 2)

   (NOTE: Use 1.0 percent of sodium carbonate for every 6 gallons of water.)

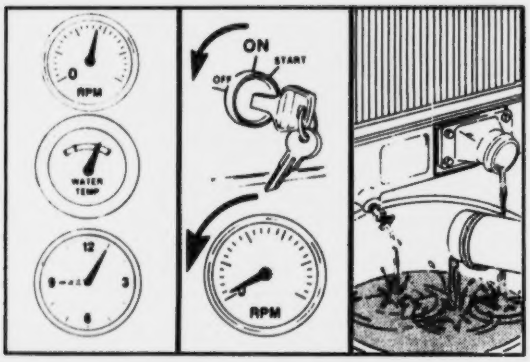
   FIGURE 2



   (CAUTION: Do not install the radiator cap or new coolant filters.)

5. Operate the engine for 5 minutes with the coolant temperature above 180°F. (Figure 3)

   FIGURE 3



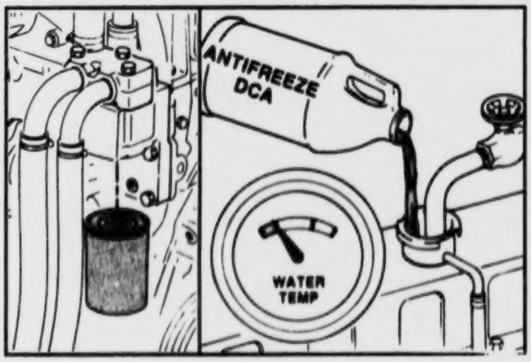
6. Shut off the engine and drain the cooling system. (Figure 3)
7. Fill the cooling system with clean water.
8. Operate the engine for 5 minutes with the coolant temperature above 180°F.
9. Shut off the engine and drain the cooling system.

   (NOTE: If the water being drained is still dirty, the system must be flushed again until the water is clean.)

JOB SHEET #3

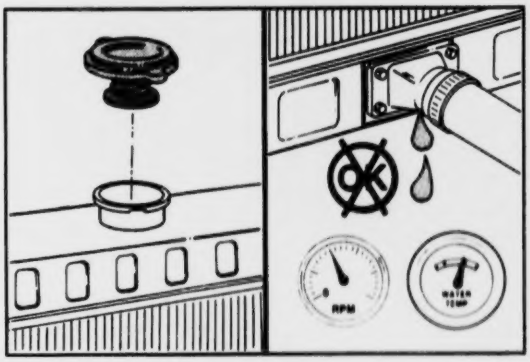
10. Install a new coolant filter, and fill the cooling system with a mixture of 50% antifreeze and 50% water. (Figure 4)

FIGURE 4


ANTIFREEZE
DCA
WATER
TEMP

11. Install the pressure cap and operate the engine; check for coolant leaks. (Figure 5)

FIGURE 5


OK
RPM
WATER
TEMP

COOLANTS AND COOLING SYSTEMS
UNIT II-C

PRACTICAL TEST
JOB SHEET #1 — TEST FOR COMBUSTION LEAKAGE INTO THE COOLING SYSTEM

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Operated engine to reach operating temperature.	______	______
4. Drained coolant from system.	______	______
5. Removed thermostat from the system.	______	______
6. Refilled system with coolant.	______	______
7. Operated engine and observed for air bubbles.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Evaluation of the cooling system				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

PRACTICAL TEST
JOB SHEET #2 — TEST FOR AIR IN COOLING SYSTEM

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Used shop safety precautions.	______	______
3. Drained coolant from system.	______	______
4. Removed top radiator hose.	______	______
5. Installed transparent plastic tube.	______	______
6. Refilled coolant system with coolant.	______	______
7. Operated engine to reach operating temperature.	______	______
8. Observed plastic tube for air bubbles.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Evaluation of the cooling system				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

PRACTICAL TEST
JOB SHEET #3 — CLEAN THE COOLING SYSTEM

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Drained the cooling system.	______	______
3. Filled the cooling system with acid and water.	______	______
4. Operated engine and drained cooling system.	______	______
5. Filled engine with clean water and operated.	______	______
6. Drained cooling system and installed coolant filter and filled radiator with a mixture of water and antifreeze.	______	______
7. Operated engine and checked for leaks.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Cooling system is properly cleaned				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

NAME ________________________ SCORE ____________________

TEST

1. Match the terms related to coolants and cooling systems with the correct definitions.

_____a. Material added to coolant to prevent freezing

_____b. Liquid that absorbs and transfers heat to maintain normal engine operating temperature

_____c. Liquid solution which contains properties that will not readily boil away

_____d. Two strips of dissimilar metal welded together, one of which expands more when heated than the other

_____e. Chemical which dissolves in water to form a rustproof film on the metal

_____f. Mixture of air and water

_____g. Device over radiator to maintain temperature variations of coolant

1. Aeration
2. Antifreeze
3. Bimetallic
4. Coolant
5. Inhibitor
6. Permanent antifreeze
7. Radiator shutters

2. Name two types of cooling systems used on modern engines.

a. ____

b. ____

TEST

3. Match the parts of a liquid cooling system with the correct functions.

_____a. Releases heat to atmosphere; reservoir for enough liquid coolant to operate engine

_____b. Separate tank in cooling system that allows for heat expansion of coolant

_____c. Relieves pressure from too much heat; lets in air pressure as liquid cools

_____d. Forces cooling air through radiator core to more quickly dissipate heat

_____e. Circulates coolant through the system

_____f. Transmits power from engine crankshaft to drive fan and water pump

_____g. Controls the flow of coolant to radiator to maintain correct operating temperatures

_____h. Flexible connections between engine and other parts of cooling system

_____i. Medium which carries away excess heat from engine

_____j. Used in some engines to soften the water and remove dirt

1. Coolant
2. Coolant filter
3. Expansion tank
4. Fan
5. Fan belt
6. Hoses
7. Pressure cap
8. Radiator
9. Thermostat
10. Water pump

4. Complete the following list of statements concerning the parts of an air cooled engine and their functions.

a. Direct cooling system — Forces air by the cylinder at all times _____________

____

b. Fin head and cylinder blocks — Allow cool air to go by the head and cylinders to _________________________

c. _________________________ — Brings air into chambers in a swirling motion for more efficient combustion process

5. List three requirements of a good antifreeze.

a. ____

b. ____

c. ____

TEST

6. List four preventive maintenance procedures for maintaining a cooling system.

   a. ______

   b. ______

   c. ______

   d. ______

7. Name two functions of the cooling system.

   a. ______

   b. ______

8. List four effects of an engine running too hot.

   a. ______

   b. ______

   c. ______

   d. ______

9. List three effects of an engine running too cold.

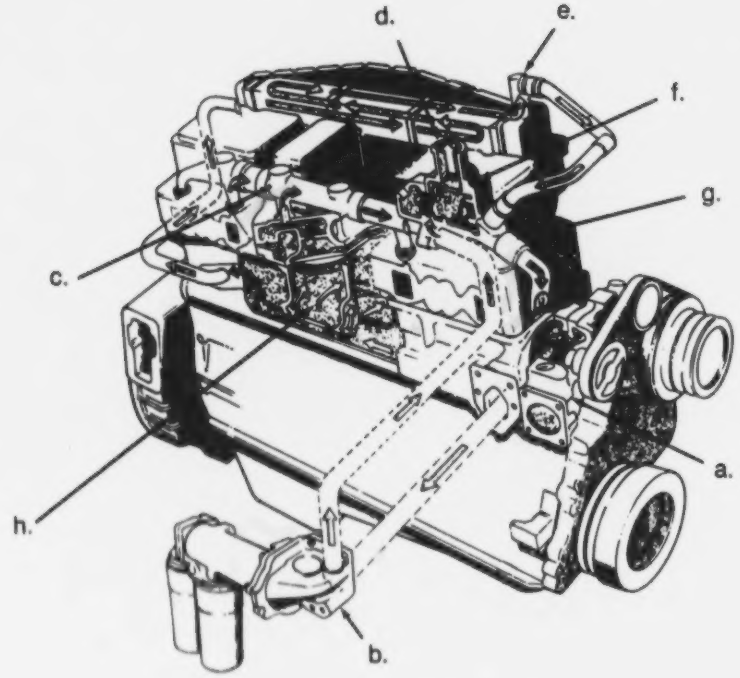
   a. ______

   b. ______

   c. ______

TEST

10. Identify the parts in a liquid cooling system.



a. ____________________________ b. ____________________________

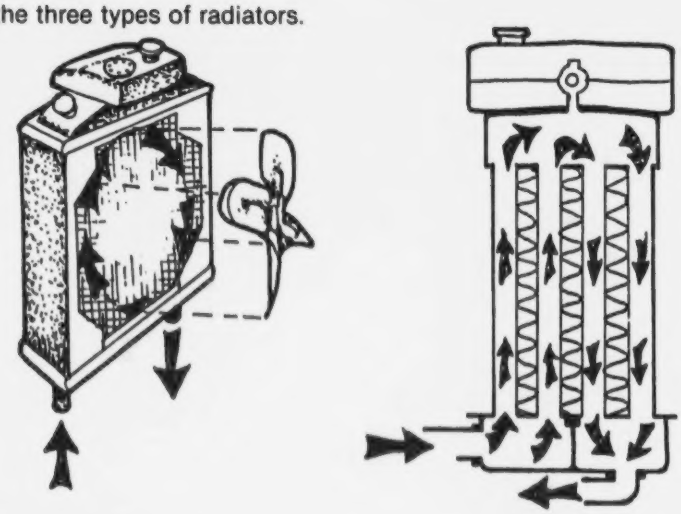
c. ____________________________ d. ____________________________

e. ____________________________ f. ____________________________

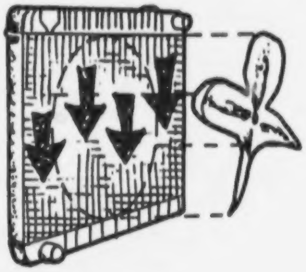
g. ____________________________ h. ____________________________

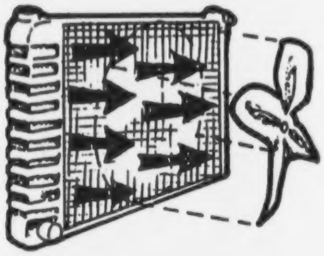
TEST

11. Identify the three types of radiators.



a. ______________________





b. ______________________ c. ______________________

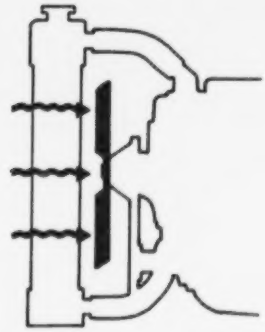
12. Name two functions of the radiator cap.

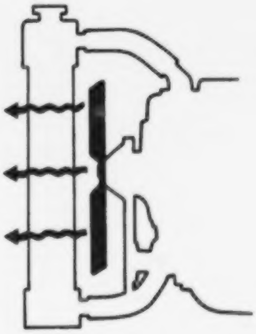
a. ______________________

b. ______________________

TEST

13. Identify two types of fans used in cooling systems.





a. ______________________________ b. ______________________________

14. Name two types of fan controls.

a. ______________________________

b. ______________________________

15. Name two types of temperature gauges.

a. ______________________________

b. ______________________________

16. List three purposes for using a coolant filter or conditioner in the cooling system.

a. ______________________________

b. ______________________________

c. ______________________________

17. Select functions of the thermostat by placing an "X" beside each function.

_____a. Permits rapid engine warm-up when closed

_____b. Permits efficient cooling when open

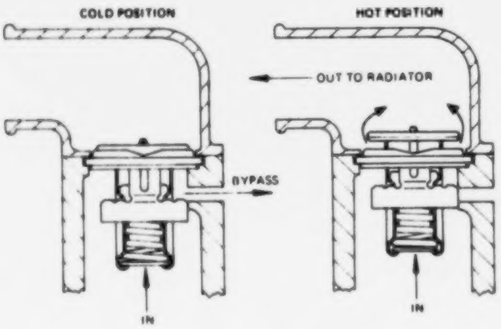
_____c. Permits rapid engine warm-up when open

_____d. Permits efficient cooling when closed

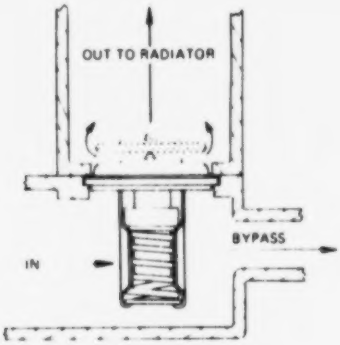
_____e. Provides automatic control of the engine temperature

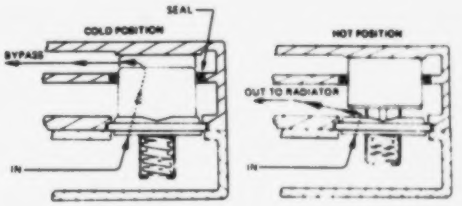
TEST

18. Identify the three types of thermostats.


COLD POSITION
HOT POSITION
OUT TO RADIATOR
BYPASS
IN
IN

a. ______________________________


OUT TO RADIATOR
BYPASS
IN


SEAL
COLD POSITION
HOT POSITION
BYPASS
OUT TO RADIATOR
IN
IN

b. ______________________________ c. ______________________________

19. Select common materials that may restrict radiator coolant flow by placing an "X" beside each restricting material.

_____a. Oil

_____b. Hair

_____c. Suds

_____d. Lime

_____e. Scale

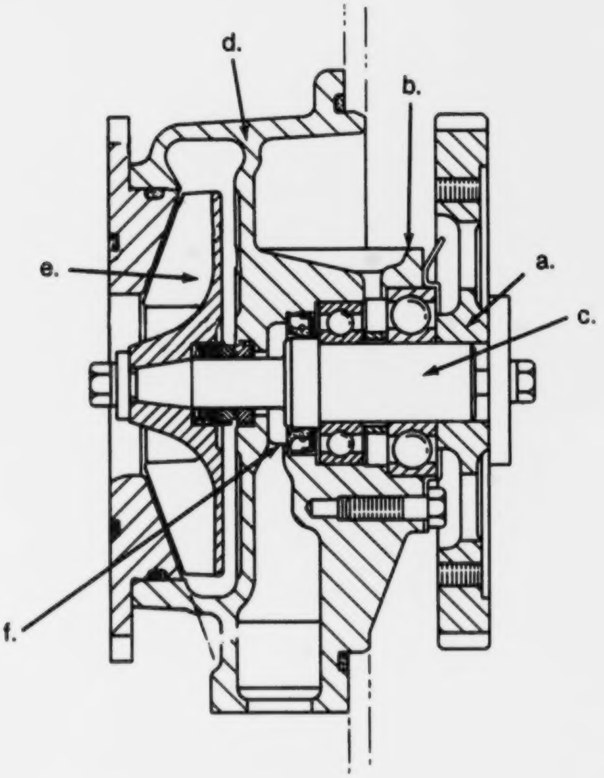
_____f. Mud

_____g. Rust

_____h. Silicate jelly

TEST

20. Identify the primary parts of a water pump.



a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

21. Demonstrate the ability to:

   a. Test for combustion leakage into the cooling system. (Job Sheet #1)

   b. Test for air in cooling system. (Job Sheet #2)

   c. Clean the cooling system. (Job Sheet #3)

COOLANTS AND COOLING SYSTEMS
UNIT II-C

ANSWERS TO TEST

1. a. 2
   b. 4
   c. 6
   d. 3
   e. 5
   f. 1
   g. 7

2. a. Air
   b. Liquid

3. a. 8
   b. 3
   c. 7
   d. 4
   e. 10
   f. 5
   g. 9
   h. 6
   i. 1
   j. 2

4. a. While engine is running
   b. Draw heat away
   c. Aerodynamic intake port

5. Any three of the following:

   a. Prevents freezing
   b. Inhibits rust and corrosion
   c. Chemically stable
   d. Nonconductor of electricity
   e. Flows readily at all temperatures
   f. Conducts heat readily
   g. Resists foaming

6. Any four of the following:

   a. Inspect for system deterioration
   b. Prevent corrosion and deposits
   c. Flush and clean system periodically
   d. Allow a hot engine to idle a few minutes before shutting it down
   e. Check coolant as recommended in operator's manual

7. a. Prevents engine overheating
   b. Regulates engine temperature

ANSWERS TO TEST

8. Any four of the following:

    a. Excessive wear
    b. Scoring
    c. Knock
    d. Burned piston and valves
    e. Lubrication failure
    f. Seizure of moving parts
    g. Loss of power

9. Any three of the following:

    a. Excessive wear
    b. Poor fuel economy
    c. Accumulation of water and sludge in the crankcase
    d. Loss of power

10. a. Water pump
    b. Oil cooler
    c. Water manifold
    d. Temperature sending unit
    e. Aftercooler
    f. Thermostat
    g. Bypass
    h. Engine water jacket

11. a. Multi-pass (low flow)
    b. Down-flow
    c. Cross-flow

12. a. Allows atmospheric pressure to enter the cooling system
    b. Prevents coolant from escaping at normal temperatures

13. a. Suction fan
    b. Blower fan

14. Any two of the following:

    a. Clutch
    b. Viscous
    c. Air operated
    d. Electric

ANSWERS TO TEST

15. a. Mechanical
    b. Electrical

16. a. Softens the water
    b. Removes dirt
    c. Provides a place for rust inhibitors in the filter element

17. a, b, e

18. a. Non-blocking
    b. Partial blocking
    c. Full blocking

19. a, d, e, g, h

20. a. Fan hub
    b. Pulley
    c. Bearing and shaft assembly
    d. Water pump housing
    e. Impeller
    f. Weep hole

21. Performance skills evaluated to the satisfaction of the instructor

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

UNIT OBJECTIVE

After completion of this unit, the student should be able to test an engine for air flow restriction, remove, install and test a turbocharger, and inspect and replace a roots-type blower. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to air intake and exhaust systems with the correct definitions.
2. Name parts of an air intake system.
3. Name parts of an exhaust system.
4. Match types of air cleaners with their processes.
5. Distinguish between scavenging for a two-stroke cycle engine and a four-stroke cycle engine.
6. Identify types of air induction systems.
7. Distinguish between positive displacement and centrifugal superchargers.
8. List advantages of a turbocharged engine.
9. Demonstrate the ability to:
    a. Test an engine for air flow restriction. (Job Sheet #1)

OBJECTIVE SHEET

b. Remove and install a turbocharger. (Job Sheet #2)

c. Test a turbocharger. (Job Sheet #3)

d. Inspect, remove, and install a roots-type blower. (Job Sheet #4)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Have students make a list of how weather affects an engine filtration system.
   2. Make a cutaway of a dry-type filter.
   3. Discuss the use of a blacklight and fluorescent tracer to find oil leaks.
   4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

B. *In-Line 71 Service Manual.* Detroit, MI: Detroit Diesel Allison, 1986.

REFERENCES USED IN DEVELOPING THIS UNIT

C. Schulz, Erich V. *Diesel Mechanics.* 2nd ed. Dallas: McGraw-Hill Book Company, 1983.

D. *Troubleshooting and Repair Manual-L10 Engines.* Columbus, IN: Cummins Engine Company, Inc., 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Filmstrips

1. *Air Induction Systems* (26 slides and script)
   Order #J#G01306
   Caterpillar Tractor Co.
   Literature Orders Section
   1335 S.W. Washington
   Peoria, IL 61602

2. *Troubleshooting the Air Induction System* (53 slides and script)
   Order #SESV1316
   Caterpillar Tractor Co.
   Literature Orders Section
   1335 S.W. Washington
   Peoria, IL 61602

822

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

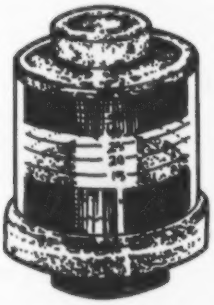
INFORMATION SHEET

I. **Terms and definitions**

A. Aftercooler or intercooler — A radiator device used on turbocharged engines to cool the air after it leaves the turbocharger (Transparency 1)

(NOTE: Aftercoolers are called intercoolers by some manufacturers. They can be air to water or air to air.)

B. Air cleaner indicator — A device with a colored piston that tells the operator when the air cleaner needs servicing



C. Filter — Unit containing an element of varying degrees of fineness to trap foreign particles

D. Manifold — Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet

E. Naturally aspirated — Engine which is not supercharged

F. Port — Opening in a cylinder block or liner for intake and/or exhaust air on two-cycle engines

G. Precleaner — Device to collect dirt from the air before it enters the main air cleaner

H. Roots-type blower — Positive displacement blower to raise intake air above atmospheric pressure

I. Scavenging — Using fresh air to push air out of the cylinders during the exhaust stroke

J. Supercharging — Any method of charging cylinders with fresh air above atmospheric pressure on the intake stroke

INFORMATION SHEET

K. Turbocharger — Exhaust-driven turbine which drives a centrifugal compressor

L. Valve — Device for sealing the intake and/or exhaust ports in a cylinder head

II. **Parts of an air intake system**

A. Precleaner (air cleaner)

B. Supercharger (if used)

C. Intake manifold

D. Piping

E. Intake valves or ports

III. **Parts of an exhaust system**

A. Ports and/or valves

B. Exhaust manifold

C. Piping

D. Muffler

E. Turbocharger (if used)

IV. **Types of air cleaners**

A. Centrifugal type — Uses centrifugal force to clean the air; used along with either an oil bath or dry type air cleaner (precleaner). (Transparency 2)

B. Oil-bath type — Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump. (Transparency 3)

INFORMATION SHEET

C. Dry element type — A dry type filter cartridge composed of paper that contains resin. (Transparency 4)

(NOTE: Some air cleaners use exhaust gas to clean the dirt out of the bottom of the filters.)

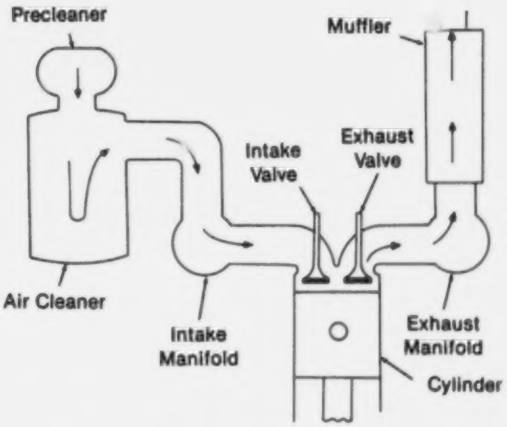
V. Scavenging

A. Two-stroke cycle — At 91½°ATDC the exhaust valve opens and exhaust gases flow into the exhaust manifold. At 132° ATDC the piston uncovers the inlet ports, blower pressure expels the remaining gases out the exhaust valves, and the cylinder is charged with fresh air. (Transparency 5)

B. Four-stroke cycle — At 28°BTDC on the exhaust stroke, the intake valve opens. The flow of the exhaust gas creates low pressure in the combustion chamber which allows fresh air to enter the cylinder. The engine is designed for valve overlap, a brief condition allowing both intake and exhaust valves to remain open simultaneously. This 51° duration (overlap) forces out the exhaust gases and draws in fresh air. (Transparency 6)

VI. Types of air induction systems

A. Naturally aspirated



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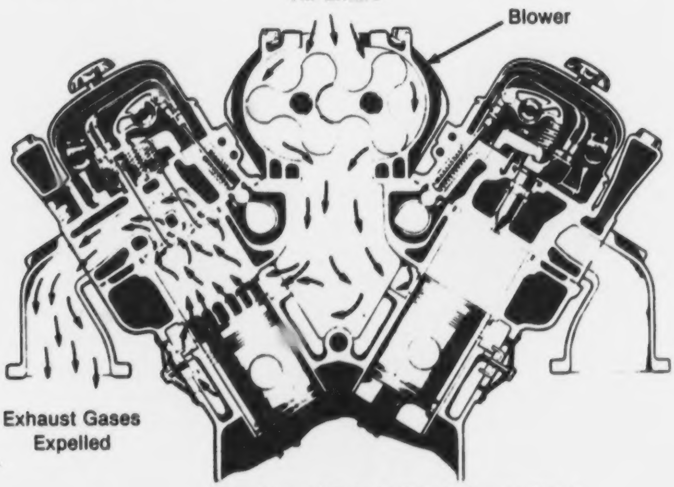
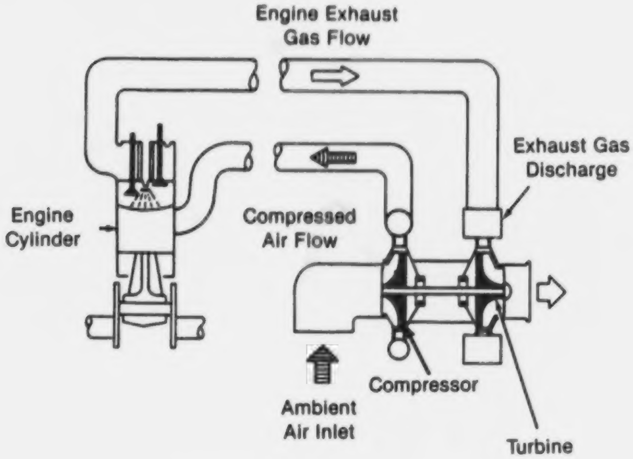
INFORMATION SHEET

B. Roots-type blower


Air Enters
Blower
Exhaust Gases Expelled

(Courtesy of Detroit Diesel Corporation.)

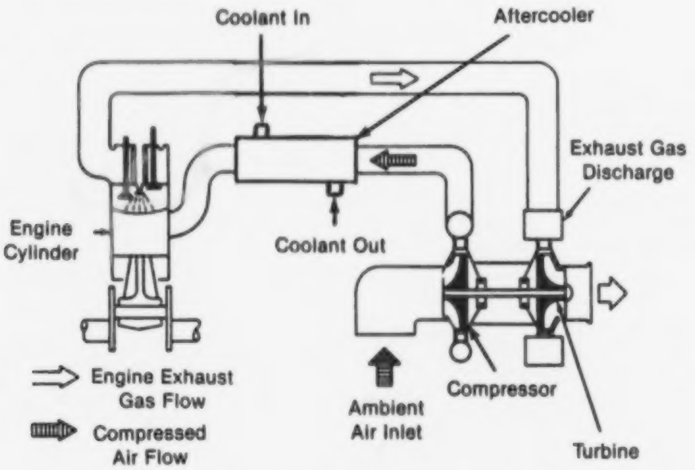
C. Turbocharger


Engine Exhaust Gas Flow
Exhaust Gas Discharge
Engine Cylinder
Compressed Air Flow
Compressor
Ambient Air Inlet
Turbine

(Courtesy of Detroit Diesel Corporation.)

INFORMATION SHEET

D. Turbocharged and aftercooled


Coolant In
Aftercooler
Exhaust Gas Discharge
Engine Cylinder
Coolant Out
Engine Exhaust Gas Flow
Compressed Air Flow
Ambient Air Inlet
Compressor
Turbine

(Courtesy of Detroit Diesel Corporation.)

(NOTE: Manufacturers use combinations of these systems on some engines.)

VII. **Types of superchargers**

A. Positive displacement (Transparency 7)

(NOTE: The roots-type blower is a positive-displacement supercharger.)

1. Driven by a chain, belt, or gear
2. Resembles oil pumps in design

B. Centrifugal (Transparencies 8 and 9)

(NOTE: Turbochargers are exhaust driven centrifugal type superchargers.)

1. Driven by engine, engine exhaust, or separate motors
2. Impeller normally moves thirty times engine speed

INFORMATION SHEET

VIII. Advantages of a turbocharged engine

A. Increases horsepower output of a given displacement engine

B. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

C. Cost of a turbocharged engine is less on a dollar per horsepower basis

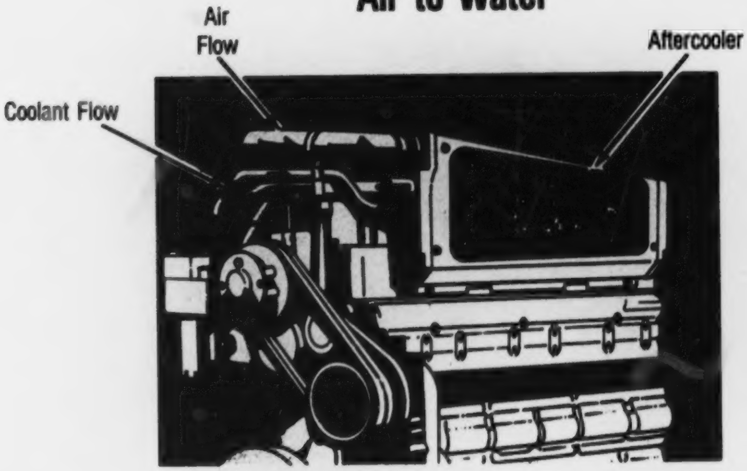
D. Maintains horsepower at higher altitudes

(NOTE: Naturally aspirated engines loose three percent of horsepower per 1000 feet of altitude.)

E. Reduces exhaust smoke by supplying excess air to reduce exhaust density

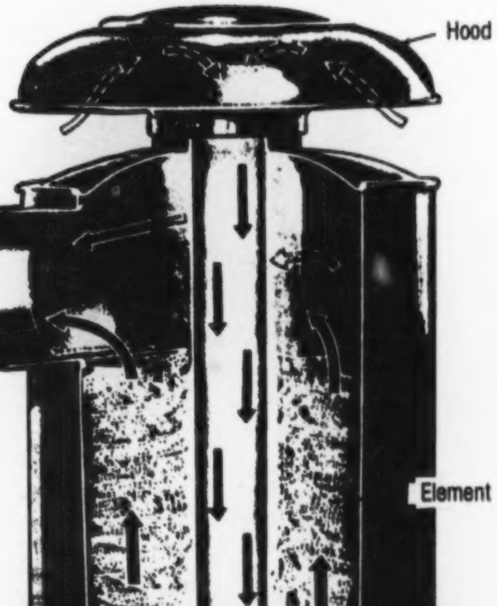
Types of Aftercoolers or Intercoolers

Air to Water

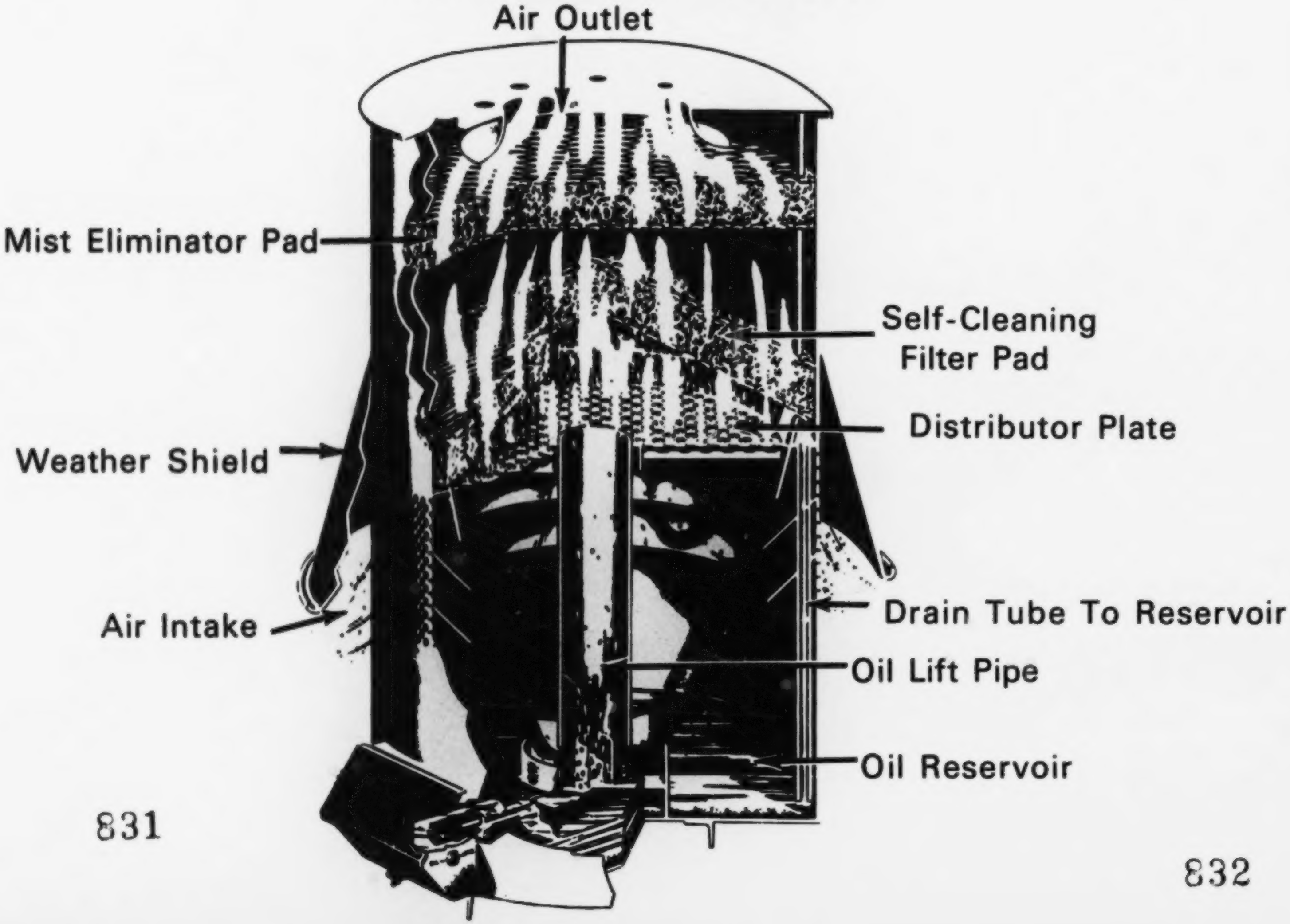

Air Flow
Aftercooler
Coolant Flow

(Courtesy of Cummins Engine Company, Inc.)

Precleaner


Hood
Element

Oil Bath Air Cleaner


Air Outlet
Mist Eliminator Pad
Self-Cleaning Filter Pad
Distributor Plate
Weather Shield
Air Intake
Drain Tube To Reservoir
Oil Lift Pipe
Oil Reservoir

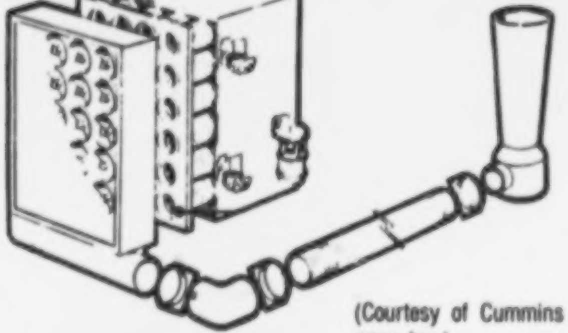
831

832

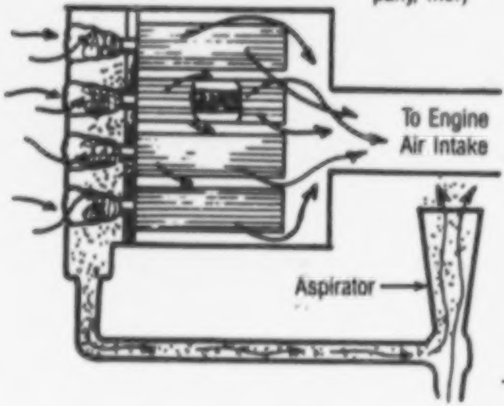
TM 3

D-113-C

Dry Type Air Cleaner

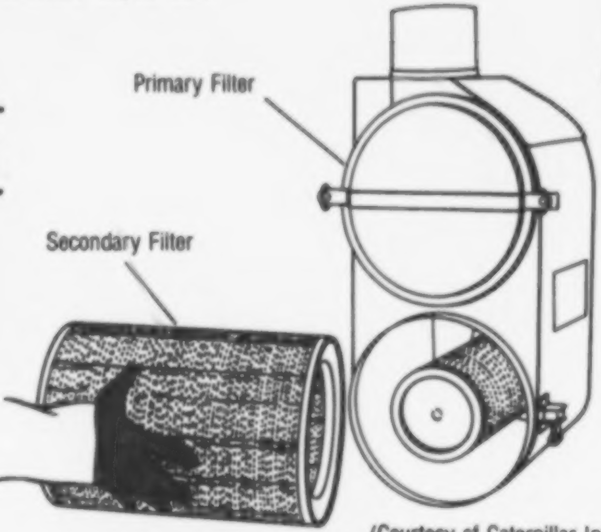


(Courtesy of Cummins Engine Company, Inc.)


To Engine
Air Intake
Aspirator

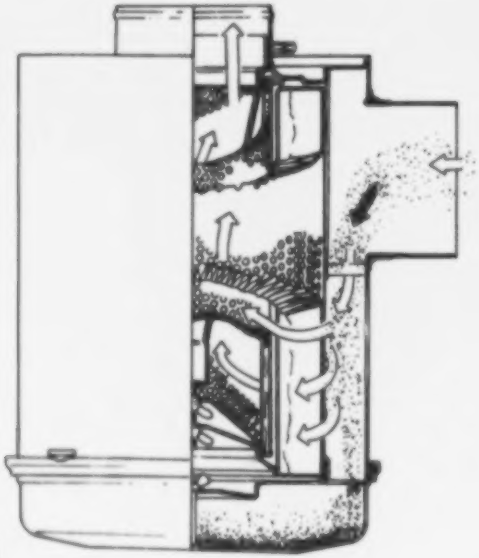
Farr Two-Stage

Uses exhaust from engine to remove dirt from bottom of filter.


Primary Filter
Secondary Filter

(Courtesy of Caterpillar Inc.)

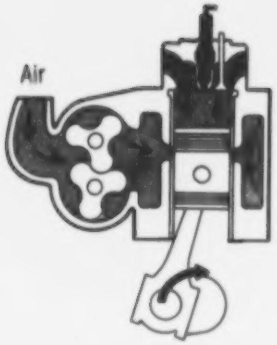
Two-Stage



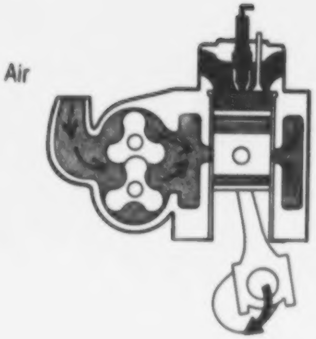
Dual Element

(Courtesy of Cummins Engine Company, Inc.)

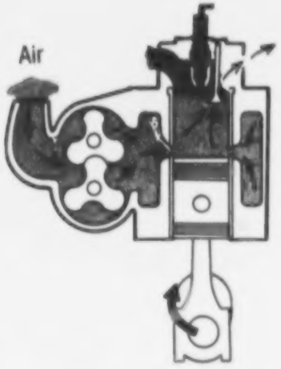
Two-Stroke Cycle Scavenging



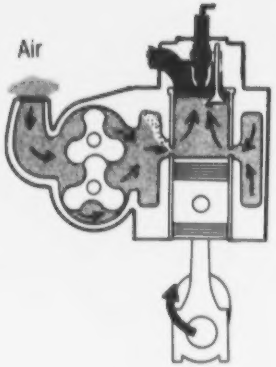
Compression Stroke



Power Stroke



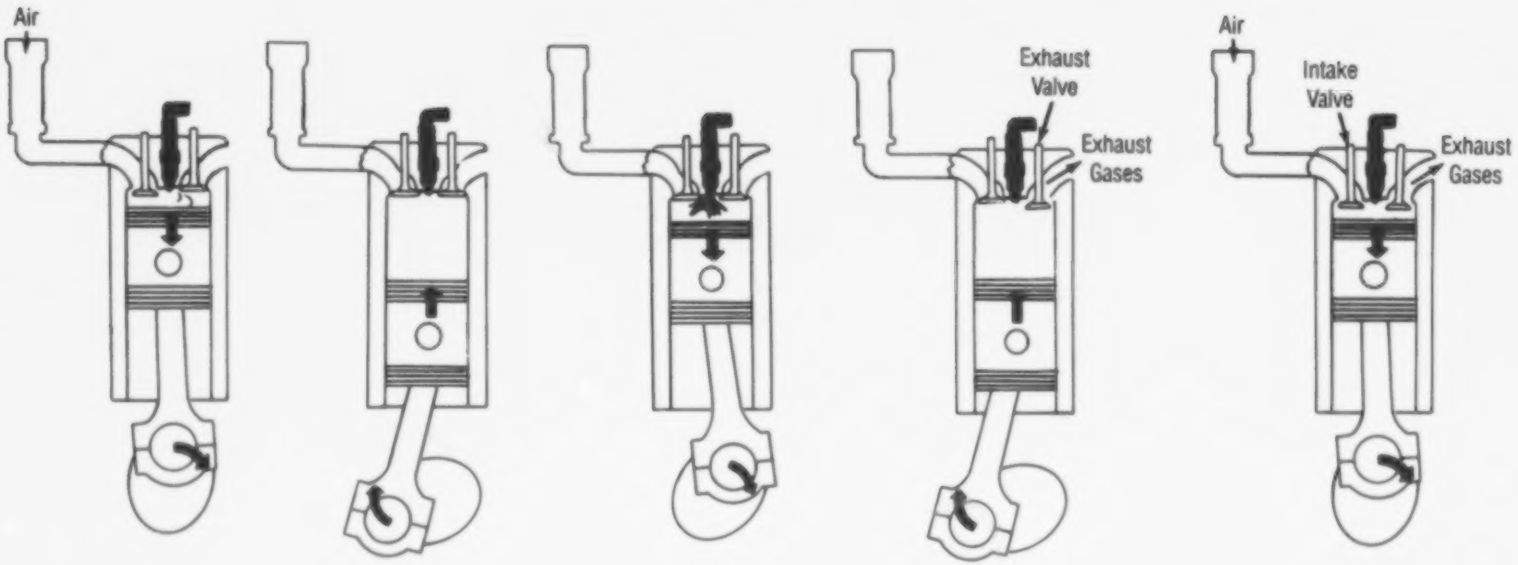
Exhaust Stroke



Intake Stroke

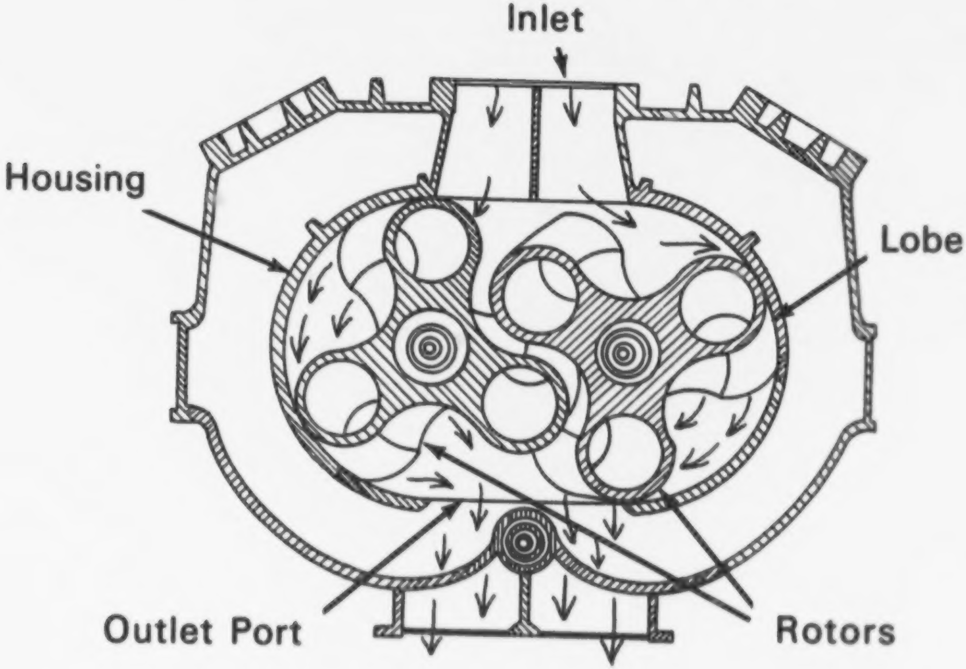
Scavenging

Four-Stroke Cycle Scavenging


Air
Exhaust Valve
Exhaust Gases
Air
Intake Valve
Exhaust Gases

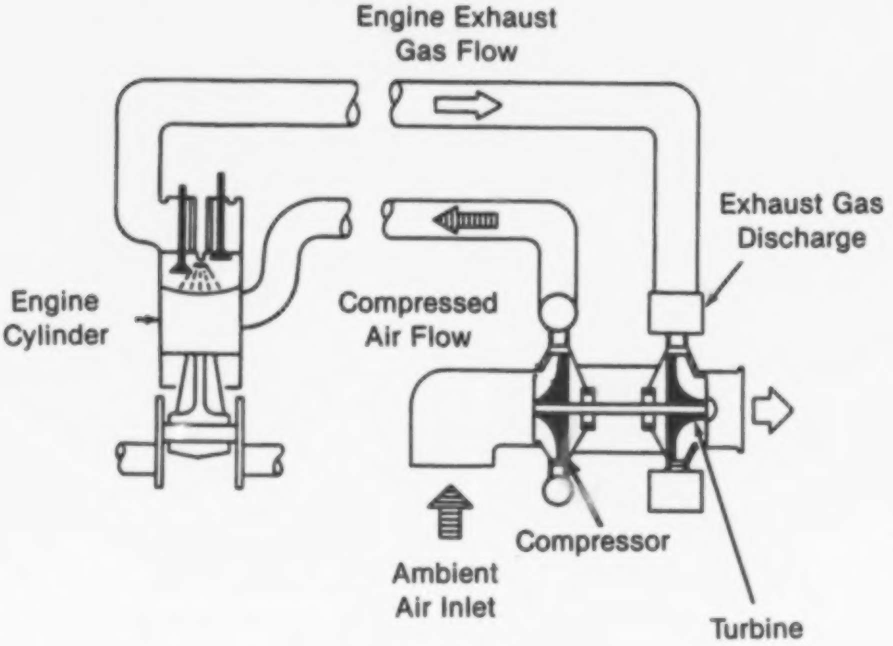
Intake Stroke **Compression Stroke** **Power Stroke** **Exhaust Stroke** **Scavenging**

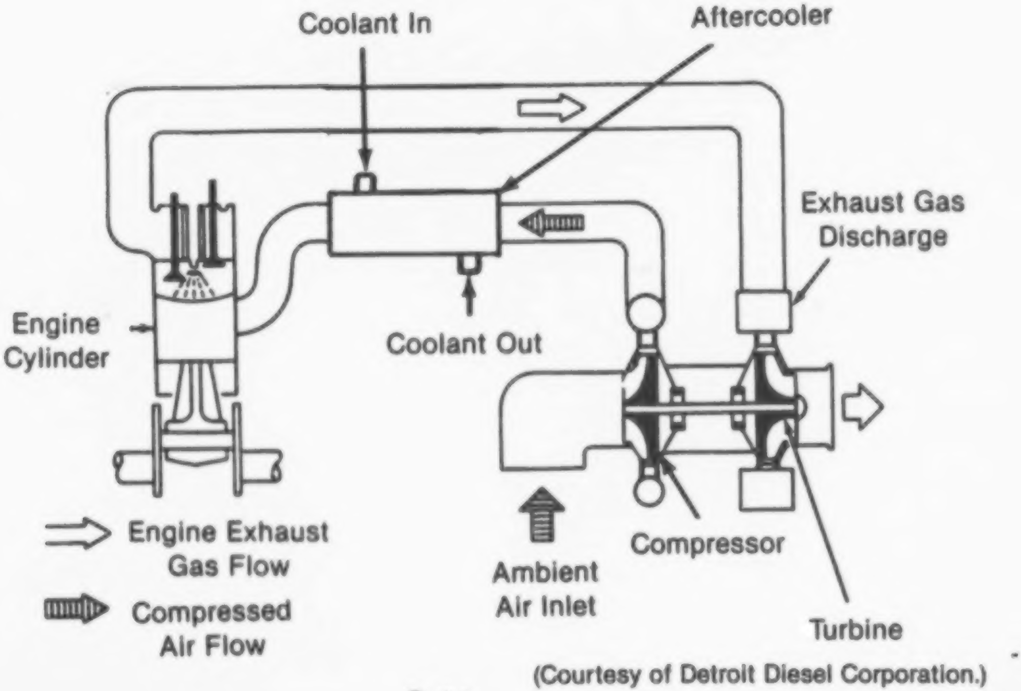
Roots-Type Blower


Inlet
Housing
Lobe
Outlet Port
Rotors

TM 7

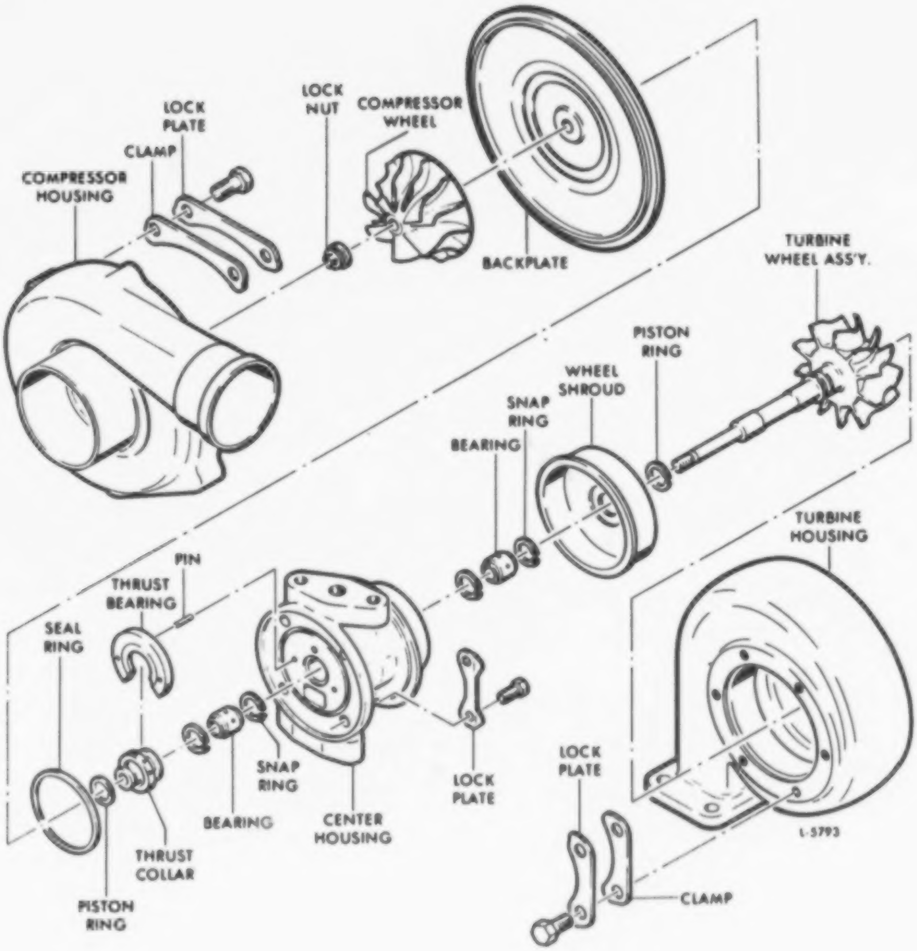
Turbocharger


Engine Exhaust
Gas Flow
Exhaust Gas
Discharge
Engine
Cylinder
Compressed
Air Flow
Compressor
Ambient
Air Inlet
Turbine


Coolant In
Aftercooler
Exhaust Gas
Discharge
Engine
Cylinder
Coolant Out
Compressor
Ambient
Air Inlet
Turbine
⇒ Engine Exhaust
Gas Flow
➡ Compressed
Air Flow

(Courtesy of Detroit Diesel Corporation.)

Turbocharger Details


LOCK PLATE
LOCK NUT
COMPRESSOR WHEEL
CLAMP
COMPRESSOR HOUSING
BACKPLATE
TURBINE WHEEL ASS'Y.
PISTON RING
WHEEL SHROUD
SNAP RING
BEARING
TURBINE HOUSING
PIN
THRUST BEARING
SEAL RING
SNAP RING
BEARING
CENTER HOUSING
LOCK PLATE
LOCK PLATE
THRUST COLLAR
PISTON RING
CLAMP
L-5793

(Courtesy of Detroit Diesel Corporation.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

JOB SHEET #1 — TEST AN ENGINE FOR AIR FLOW RESTRICTION

A. Tools and materials

1. Manometer
2. Basic hand tool set
3. Live engine
4. Shop towels
5. Engine technical manual
6. Safety glasses

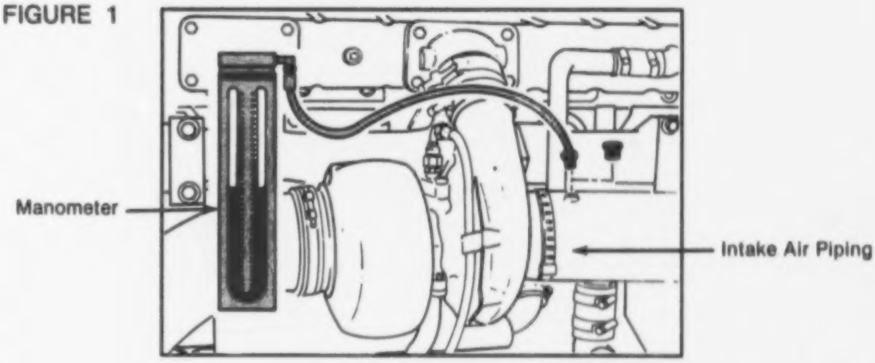
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Locate the intake air piping and connect a manometer. (Figure 1)

   (CAUTION: If engine has a turbocharger, install the gauge adapter at a right angle to the air flow. This must be installed close to the turbocharger.)

FIGURE 1



2. Operate the engine at full throttle.

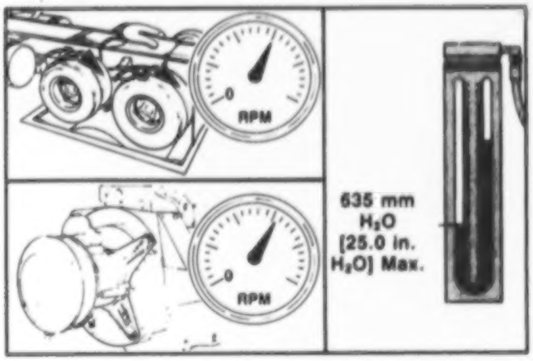
   (NOTE: Naturally aspirated engines measure at high idle RPM.)

(Figures 1-4 courtesy of Cummins Engine Company, Inc.)

JOB SHEET #1

3. Observe the manometer reading and compare to the specifications in the engine technical manual. (Figure 2)

FIGURE 2

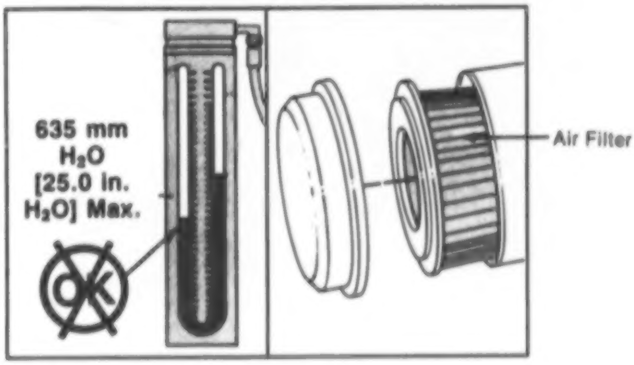

0
RPM
0
RPM
635 mm
H_2O
[25.0 in.
H_2O] Max.

(NOTE: If restriction exceeds specification, proceed to Steps 4 and 5.)

4. The air filter element should be cleaned and replaced. (Figure 3)

(NOTE: Refer to the equipment technical manual for instructions.)

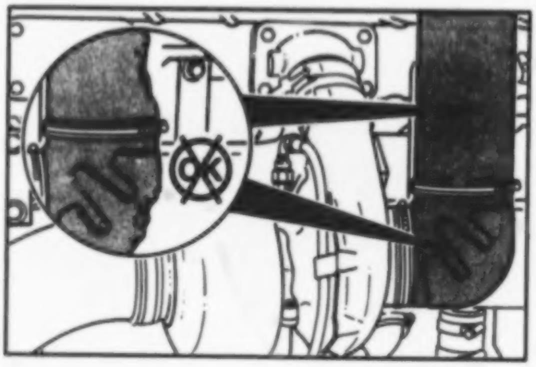
FIGURE 3


635 mm
H_2O
[25.0 in.
H_2O] Max.
OK
Air Filter

JOB SHEET #1

5. Look for dents or damage to the intake air piping. (Figure 4)

FIGURE 4



6. Remove test equipment.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

JOB SHEET #2 — REMOVE AND INSTALL A TURBOCHARGER

A. Tools and materials

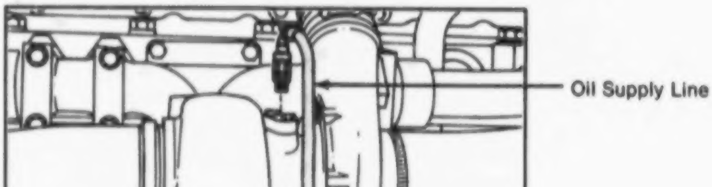
1. Engine with turbocharger
2. Basic hand tool set
3. Torque wrench
4. Crocus cloth
5. Eye protection
6. Shop towels
7. Appropriate service manual

B. Procedure

(CAUTION: Follow all safety procedures.)

1. Disconnect the oil supply line at the turbocharger only. (Figure 1)

FIGURE 1



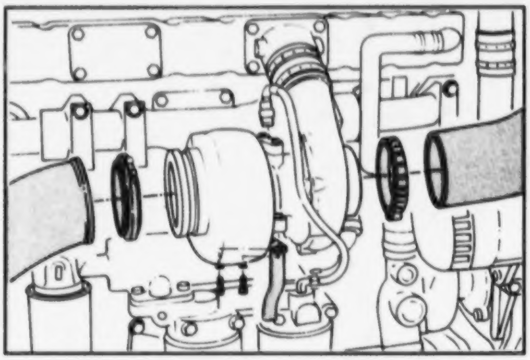
2. Disconnect the oil drain line at the turbocharger. (Figure 1)

(Figures 1-9 courtesy of Cummins Engine Company, Inc.)

JOB SHEET #2

3. Locate the intake and exhaust air pipes at each end of the turbocharger and disconnect. (Figure 2)

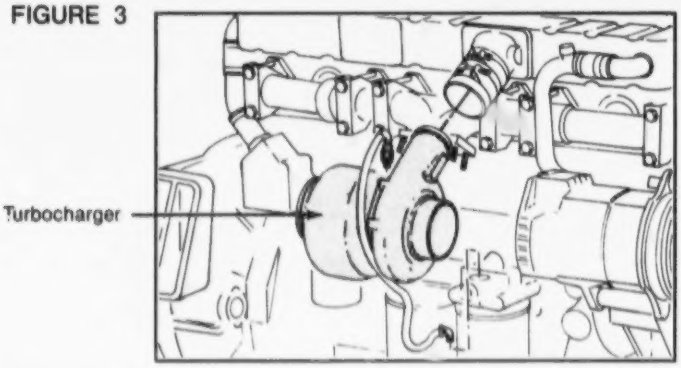
FIGURE 2



4. Back off the clamp screws on the aftercooler air inlet connection.

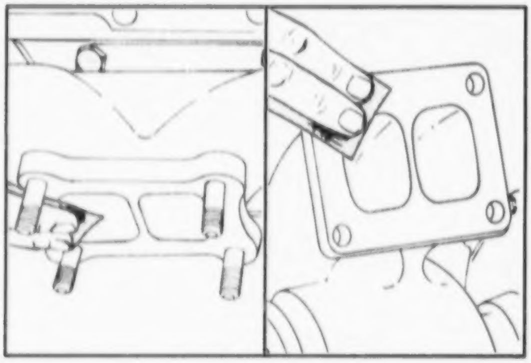
5. Remove the turbocharger mounting nuts and gasket. If the engine does not have an aftercooler, loosen the clamp on the intake manifold connection. (Figure 3)

FIGURE 3



6. Use an emery cloth or file to clean the turbocharger and exhaust manifold gasket. (Figure 4)

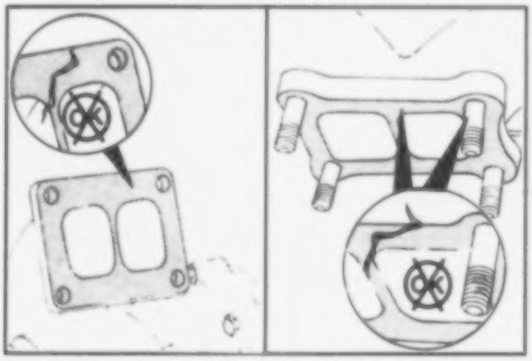
FIGURE 4



JOB SHEET #2

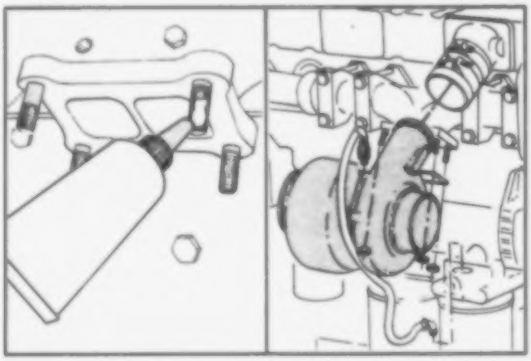
7. Look for cracks and errosion on the turbocharger, exhaust manifold gasket surfaces, and mounting studs. (Figure 5)

FIGURE 5



8. Install the turbocharger with a new gasket and start the mounting nuts. (Figure 6)

FIGURE 6

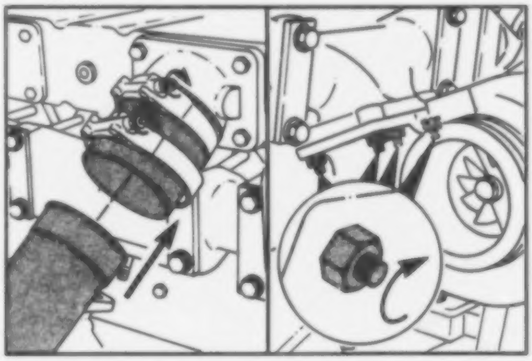


(NOTE: Do not tighten the nuts until the air inlet hose is installed on the turbocharger.)

JOB SHEET #2

9. Install the air inlet hose on the aftercooler. If the engine does not have an aftercooler, install the air inlet hose on the intake manifold connection. (Figure 7)

FIGURE 7

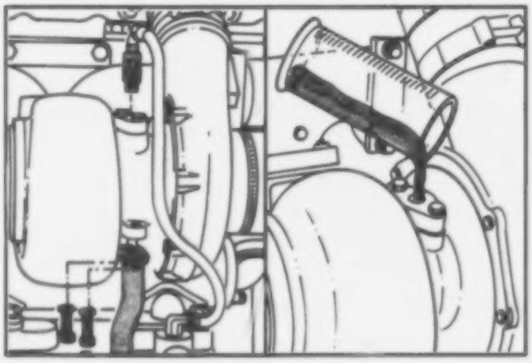


10. Refer to the manufacturers' specifications to tighten the turbocharger mounting nuts. (Figure 7)

11. Tighten hose clamps on each hose.

12. Reconnect the oil drain line and tighten bolts. (Figure 8)

FIGURE 8



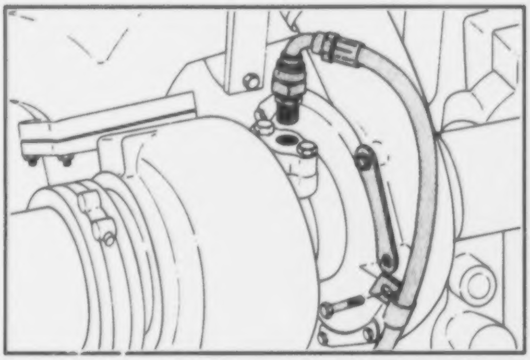
13. Pour 2 to 3 ounces of clean engine oil in the oil supply line fitting. (Figure 8)

JOB SHEET #2

14. Reconnect the oil supply line and tighten the bolts or fitting. (Figure 9)

    (NOTE: Make sure you reconnect all brackets to the oil line to prevent the line from breaking.)

FIGURE 9



15. Install the intake and exhaust pipes.

16. Operate the engine and check for air leaks on the inlet piping and connections.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

JOB SHEET #3 — TEST A TURBOCHARGER

A. Tools and materials

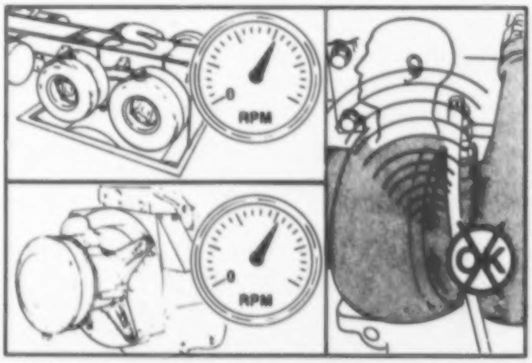
1. Basic hand tool set
2. Turbocharger
3. Dial depth gauge
4. Wire type feeler gauge
5. Shop towels
6. Safety glasses

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Inspect the mounting and connections of turbocharger to be certain they are secure and there is no leakage of oil or air.
2. Inspect and service air cleaner.
3. Operate the engine at full throttle. (Figure 1)

FIGURE 1



(Courtesy of Cummins Engine company, Inc.)

4. Listen for unusual high pitch noise or for unusual vibration. (Figure 1)

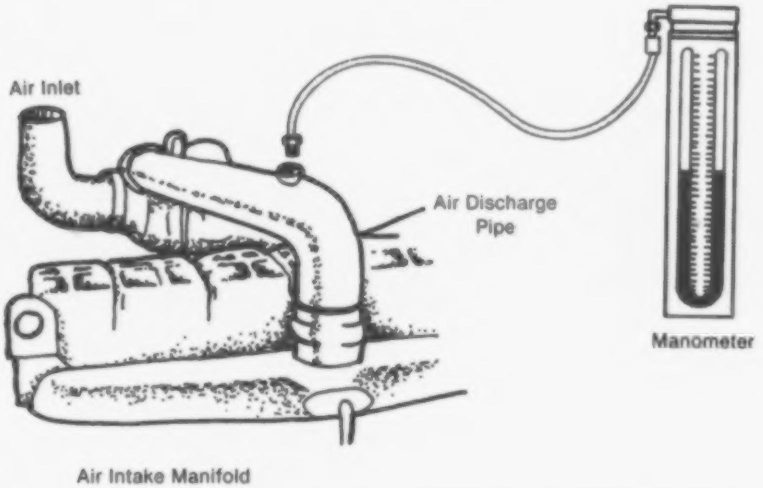
(NOTE: Replace turbocharger if the noise or vibration is not originating from damaged or leaking air piping.)

JOB SHEET #3

5. Test intake manifold pressure ("boost").

   a. Connect a manometer to the air discharge pipe. (Figure 2)

   FIGURE 2



   b. Operate engine at full load and rated speed and measure intake manifold pressure.

   c. Operate engine at full load and the specified lower speed and measure intake manifold pressure.

   d. If the boost pressure is not within specification, check air intake system for restricted compressor wheel or dirt and oil deposits, and correct turbocharger applications.

6. Remove the air discharge pipes, and check the compressor housing and pipe for the presence of oil.

   (NOTE: All turbochargers contain a small but harmless amount of engine oil. If you find heavy deposits of oil, it is an indication of seal leakage.)

7. Check radial clearance.

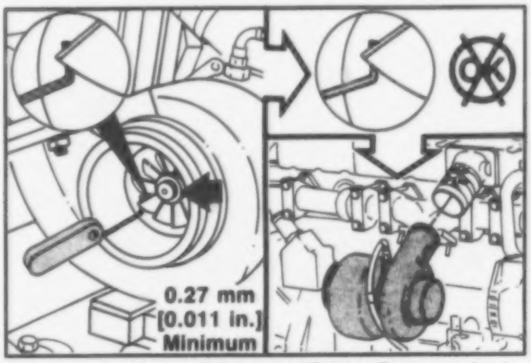
   a. Remove the inlet and exhaust pipes from the turbocharger.

   (NOTE: Check for oil in the exhaust pipe.)

JOB SHEET #3

b. Push the turbine wheel (on the exhaust outlet) in toward the housing. Using a wire type feeler gauge, measure the distance between the turbine blades and housing. (Figure 3)

FIGURE 3

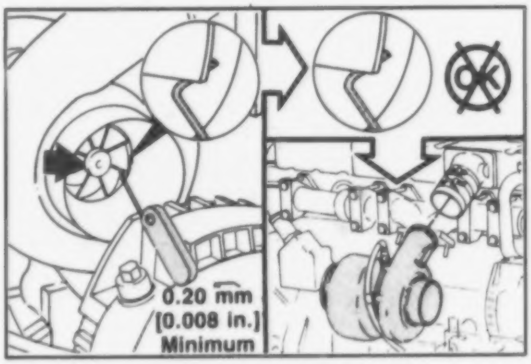


(Figures 3-5 courtesy of Cummins Engine Company, Inc.)

(NOTE: Check the engine manual specifications. If the clearance does not meet the specification, remove the turbocharger and replace.)

c. Repeat this procedure for the compression impeller. (Figure 4)

FIGURE 4



(NOTE: Replace the turbocharger if the clearance does not meet specification.)

8. Check axial clearance.

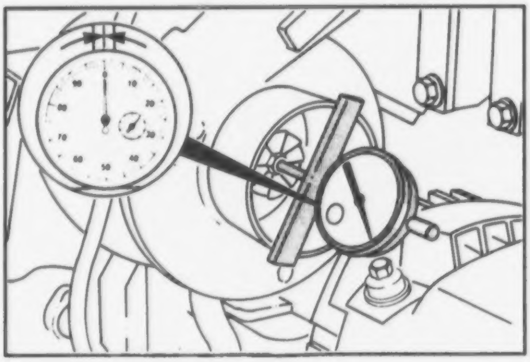
   a. Install dial depth gauge. (Figure 5)

   b. Push the rotor assembly away from the gauge.

JOB SHEET #3

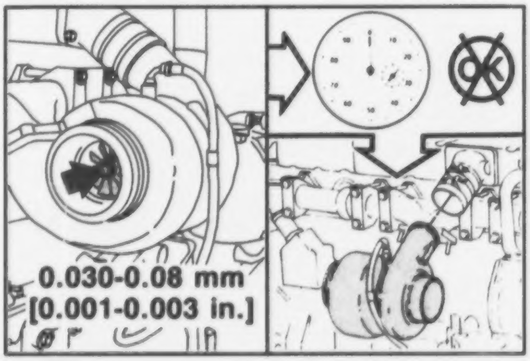
c. Zero the dial indicator. (Figure 5)

FIGURE 5



d. Push the rotor assembly in and out to measure the end clearance. Record the reading. (Figure 6)

FIGURE 6



(NOTE: If the clearance does not meet the specifications, replace the turbocharger.)

e. Remove dial depth gauge.

9. Install intake and exhaust piping.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

JOB SHEET #4 — INSPECT, REMOVE, AND INSTALL A ROOTS-TYPE BLOWER

A. Tools and materials

1. Basic hand tools
2. Drop light
3. Shop towels
4. Safety glasses
5. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: A blower may be inspected for defective conditions without being removed from the engine. If blower fails any of the following tests, remove from the engine and overhaul or replace.)

1. Inspect blower.

   a. Remove air cleaners, blower air inlet housing, or any other parts interfering with the air inlet system. (Figure 1)

   (CAUTION: When blower rotors are exposed and engine is in operation, keep fingers, clothing, and any loose parts away from the blower air inlet.)

FIGURE 1

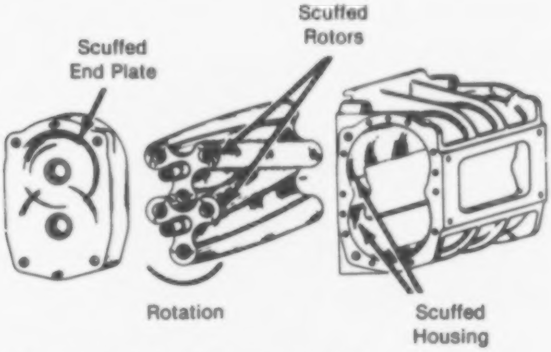
Air Shutdown Housing
Blower

JOB SHEET #4

b. Inspect rotors for deep scratches around intake and on rotor tips.

c. Turn engine over by hand and inspect rotors for signs of rubbing between the rotors. (Figure 2)

FIGURE 2



(Courtesy of Detroit Diesel Corporation.)

d. Start engine and run at idle; observe the end plates through the rotor compartment opening. (Figure 3)

(NOTE: If a seal is leaking, a thin film of oil will accumulate on the end plate.)

FIGURE 3

e. Inspect blower for a rattling sound or a harsh metallic sound.

(NOTE: This sound could indicate a defective coupling, or the clearance between the rotors has changed and blower needs to be removed.)

JOB SHEET #4

f. Kill engine.

(NOTE: If inspection reveals any defective parts, blower should be removed. If blower passes inspection, install air inlet housing and air filters, and put engine back in operation.)

2. Remove blower.

(NOTE: Removal of the blower assembly together with governor drive, water pump, fuel pump, and blower device shaft cover will be found to be advantageous in most cases.)

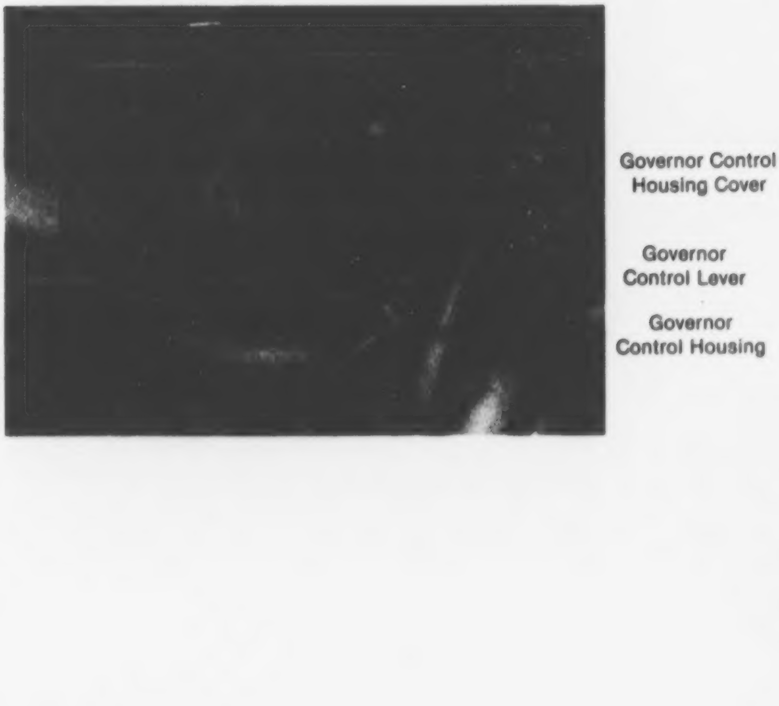
a. Drain water from cooling system.

b. Remove the valve cover.

c. Disconnect the linkage attached to the governor control levers.

d. Remove screws in the governor control housing cover, and remove cover. (Figure 4)

FIGURE 4


Governor Control Housing Cover
Governor Control Lever
Governor Control Housing

JOB SHEET #4

e. Disconnect the fuel rod from the differential lever and the injector control tube lever. (Figure 5)

FIGURE 5

Control Tube
Governor Lever
Differential Lever

f. Remove two governor-to-cylinder head bolts.

g. Disconnect the oil tube at the governor weight housing; remove bolts and cover, if used. (Figure 6)

FIGURE 6

Governor
Weight Housing

h. Remove the governor housing from the cylinder head and weight housing.

JOB SHEET #4

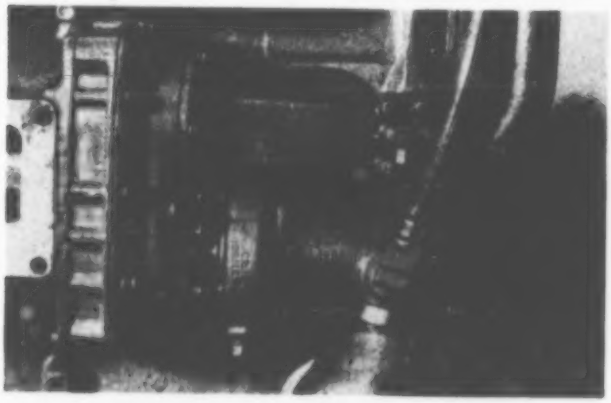
i. Disconnect the fuel lines at the fuel pump. (Figure 7)

FIGURE 7

Fuel Pump
Fuel Lines
Blower

j. Remove water pump connections at oil cooler and cylinder block. (Figure 8)

FIGURE 8



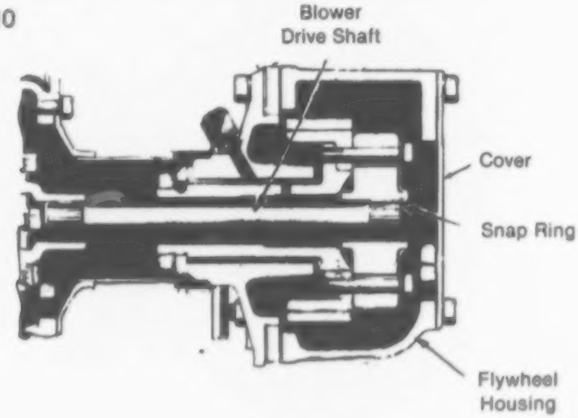
JOB SHEET #4

k. Remove air cleaners, blower air inlet housing, or any other points interfering with the air inlet system. (Figure 9)

FIGURE 9

l. Remove the six bolts that secure the flywheel hole cover, remove the snap ring, and pull the blower drive shaft out. (Figure 10)

FIGURE 10


Blower
Drive Shaft
Cover
Snap Ring
Flywheel
Housing

JOB SHEET #4

- m. Loosen the blower drive shaft cover seal clamp at the blower drive gear hub support.
- n. Remove the bolts and plain washers securing the blower to the cylinder block.
- o. Slide the blower slightly forward, withdraw the blower drive shaft cover from the seal, then lift the blower away from engine.

3. Install blower.
   - a. Install blower by reversing removal procedures.
   - b. Use nonhardening gasket sealant on all gaskets.
   - c. Hand-tighten all hex bolts before tightening to the recommended torque.
   - d. Run the engine and check for oil and water leaks.

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

PRACTICAL TEST
JOB SHEET #1 — TEST AN ENGINE FOR AIR FLOW RESTRICTION

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	_____	_____
2. Installed test equipment.	_____	_____
3. Operated engine.	_____	_____
4. Recorded reading on test instrument and compared it with specifications.	_____	_____
5. Replaced or cleaned air filter.	_____	_____
6. Inspected the intake piping.	_____	_____
7. Checked in/put away tools and materials.	_____	_____
8. Cleaned the work area.	_____	_____
9. Used proper tools correctly.	_____	_____
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	_____	_____
11. Practiced safety rules throughout procedure.	_____	_____
12. Provided satisfactory responses to questions asked.	_____	_____

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Performed steps correctly	4	3	2	1
Evaluation of test results	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

PRACTICAL TEST
JOB SHEET #2 — REMOVE AND INSTALL A TURBOCHARGER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Removed supply and drain lines.	______	______
3.	Removed intake and exhaust piping.	______	______
4.	Removed mounting nuts, turbocharger, and gasket.	______	______
5.	Cleaned turbocharger and exhaust manifold gasket surfaces.	______	______
6.	Inspected turbocharger exhaust manifold surfaces.	______	______
7.	Installed turbocharger and tightened mounting nuts and hose clamps.	______	______
8.	Installed oil supply and drain lines.	______	______
9.	Installed intake and exhaust pipes.	______	______
10.	Operated the engine and checked for leaks.	______	______
11.	Checked in/put away tools and materials.	______	______
12.	Cleaned the work area.	______	______
13.	Used proper tools correctly.	______	______
14.	Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15.	Practiced safety rules throughout procedure.	______	______
16.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Changed turbocharger; operates correctly				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

PRACTICAL TEST
JOB SHEET #3 — TEST A TURBOCHARGER

STUDENT'S NAME ____________________ DATE __________

EVALUATOR'S NAME ____________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Inspected mounting and connections.	______	______
3. Inspected and serviced air cleaner.	______	______
4. Started and operated engine.	______	______
5. Listened for unusual sounds.	______	______
6. Tested intake manifold pressure.	______	______
7. Checked for oil in compressor housing.	______	______
8. Checked radial clearance.	______	______
9. Checked axial clearance.	______	______
10. Installed intake and exhaust piping.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Performed steps correctly	4	3	2	1
Evaluation of intake manifold pressure	4	3	2	1
Evaluation of radial clearance	4	3	2	1
Evaluation of axial clearance	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

PRACTICAL TEST
JOB SHEET #4 — INSPECT, REMOVE, AND INSTALL A ROOTS-TYPE BLOWER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed air inlet housing.	______	______
3. Inspected rotors for scratches and scuff marks.	______	______
4. Started engine and checked blower for oil leaks and unusual sounds.	______	______
5. Drained the cooling system.	______	______
6. Removed governor.	______	______
7. Removed fuel lines from fuel pump.	______	______
8. Removed water pump connections.	______	______
9. Removed inlet housing and interfering parts.	______	______
10. Removed blower drive shaft.	______	______
11. Removed blower from engine.	______	______
12. Installed blower by reversing removal procedures.	______	______
13. Used nonhardening gasket sealant on gasket and tightened bolts to proper torque.	______	______
14. Ran engine and checked for oil and water leaks.	______	______
15. Checked in/put away tools and materials.	______	______
16. Cleaned the work area.	______	______
17. Used proper tools correctly.	______	______
18. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
19. Practiced safety rules throughout procedure.	______	______
20. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Evaluation of blower on the engine	4	3	2	1
Replaced blower; operates correctly	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

NAME ______________________________ SCORE ________________________

TEST

1. Match terms related to air intake and exhaust systems with the correct definitions.

______a. Unit containing an element of varying degrees of fineness to trap foreign particles

______b. Using fresh air to push air out of the cylinders during the exhaust stroke

______c. Opening in a cylinder block or liner for intake and/or exhaust air on two-cycle engines

______d. Device for sealing the intake and/or exhaust ports in a cylinder head

______e. Positive displacement blower to raise intake air above atmospheric pressure

______f. Exhaust-driven turbine which drives a centrifugal compressor

______g. Pipe or casting with multiple openings to connect multiple cylinders to one outlet or inlet

______h. Any method of charging cylinders with fresh air above atmospheric pressure on the intake stroke

______i. Engine which is not supercharged

______j. Device to collect dirt from the air before it enters the main air cleaner

______k. A radiator device used on turbocharged engines to cool the air after it leaves the turbocharger

______l. A device with a colored piston that tells the operator when the air cleaner needs servicing

1. Aftercooler or intercooler
2. Air cleaner indicator
3. Filter
4. Manifold
5. Naturally aspirated
6. Port
7. Precleaner
8. Roots-type blower
9. Scavenging
10. Supercharging
11. Turbocharger
12. Valve

TEST

2. Name four parts of an air intake system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

3. Name four parts of an exhaust system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

4. Match types of air cleaners with their processes.

_____a. Uses centrifugal force to clean the air; used along with either an oil bath or dry type air cleaner.

_____b. Cleans air by directing it through a center tube into the inner oil cup where direction of air flow is reversed causing most of the dirt to become trapped by the oil and settle in the sump.

_____c. A dry type filter cartridge composed of paper that contains resin.

1. Centrifugal type
2. Dry element type
3. Oil-bath type

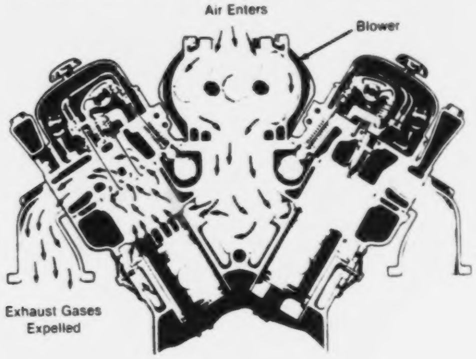
5. Distinguish between scavenging for two-stroke cycle engines and four-stroke cycle engines by placing an "X" next to the description of the four-stroke cycle scavenging.

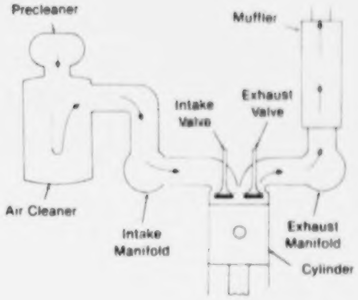
_____a. At 91½° ATDC the exhaust valve opens and exhaust gases flow into the exhaust manifold. At 132° ATDC the piston uncovers the inlet ports, blower pressure expels the remaining gases and the exhaust valves, and the cylinder is charged with fresh air.

_____b. At 28° BTDC on the exhaust stroke, the intake valve opens. The flow of the gas creates low pressure in the combustion chamber which allows fresh air to enter the cylinder. The engine is designed for valve overlap, a brief condition allowing both intake and exhaust valves to remain open simultaneously. This 51° duration (overlap) forces out the exhaust gases and draws in fresh air.

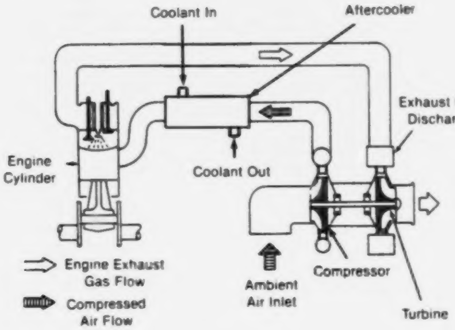
TEST

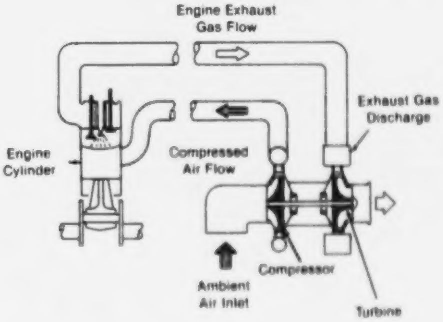
6. Identify types of air induction systems.


Air Enters
Blower
Exhaust Gases Expelled


Precleaner
Muffler
Intake Valve
Exhaust Valve
Air Cleaner
Intake Manifold
Exhaust Manifold
Cylinder

a. ______________________ b. ______________________


Coolant In
Aftercooler
Exhaust Gas Discharge
Engine Cylinder
Coolant Out
Engine Exhaust Gas Flow
Compressed Air Flow
Ambient Air Inlet
Compressor
Turbine


Engine Exhaust Gas Flow
Exhaust Gas Discharge
Engine Cylinder
Compressed Air Flow
Ambient Air Inlet
Compressor
Turbine

c. ______________________ d. ______________________

7. Distinguish between positive displacement and centrifugal superchargers by placing an "X" next to the characteristics of centrifugal superchargers.

_____a. Driven by engine, engine exhaust, or separate motors

_____b. Driven by chair, belt, or gear

_____c. Resembles oil pumps in design

_____d. Impeller normally moves thirty times engine speed

TEST

8. List four advantages of a turbocharged engine.

   a. ____

   b. ____

   c. ____

   d. ____

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Demonstrate the ability to:

   a. Test an engine for air flow restriction. (Job Sheet #1)

   b. Remove and install a turbocharger. (Job Sheet #2)

   c. Test a turbocharger. (Job Sheet #3)

   d. Inspect, remove, and install a roots-type blower. (Job Sheet #4)

AIR INTAKE AND EXHAUST SYSTEMS
UNIT III-C

ANSWERS TO TEST

1.

a.	3	g.	4
b.	9	h.	10
c.	6	i.	5
d.	12	j.	7
e.	8	k.	1
f.	11	l.	2

2. Any four of the following:

   a. Precleaner, air cleaner
   b. Supercharger (if used)
   c. Intake manifold
   d. Piping
   e. Intake valves or ports

3. Any four of the following:

   a. Ports and/or valves
   b. Exhaust manifold
   c. Piping
   d. Muffler
   e. Turbocharger (if used)

4. a. 1
   b. 3
   c. 2

5. b

6. a. Roots-type blower
   b. Naturally aspirated
   c. Turbocharger aftercooled
   d. Turbocharged

7. a, d

ANSWERS TO TEST

8. Any four of the following:

    a. Increases horsepower output of a given displacement engine
    b. Reduces weight by delivering more horsepower per pound than nonturbocharged engines
    c. Cost of a turbocharged engine is less on a dollar per horsepower basis
    d. Maintains horsepower at higher altitudes
    e. Reduces exhaust smoke by supplying excess air to reduce exhaust density

9. Performance skills evaluated to the satisfaction of the instructor

ENGINE BRAKES AND RETARDERS
UNIT IV-C

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate the ability to adjust a Jacobs engine brake, install a Jacobs engine brake, and troubleshoot a Caterpillar BrakeSaver. Competencies will be demonstrated by completing the job sheets and unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to engine brakes and retarders with the correct definitions.
2. Select true statements concerning the Jacobs engine brake operation.
3. Complete a list of troubleshooting procedures for the Jacobs engine brake.
4. Complete a list of advantages of the Jacobs engine brake.
5. Select true statements concerning the operation of the BrakeSaver.
6. Demonstrate the ability to:
    a. Adjust a Jacobs engine brake on a Detroit diesel. (Job Sheet #1)
    b. Troubleshoot a Caterpillar BrakeSaver. (Job Sheet #2)
    c. Remove a BrakeSaver on a Caterpillar diesel engine. (Job Sheet #3)
    d. Disassemble a BrakeSaver. (Job Sheet #4)

OBJECTIVE SHEET

e. Assemble a BrakeSaver. (Job Sheet #5)

f. Install a BrakeSaver. (Job Sheet #6)

g. Install a Jacobs engine brake on a Mack diesel. (Job Sheet #7)

h. Adjust slave piston of a Jacobs engine brake on a Mack diesel. (Job Sheet #8)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Discuss troubleshooting of a Jacobs engine brake system.
2. Show a Jacobs engine brake system in operation.
3. Take field trip to a truck repair shop.
4. Show parts of a Jacobs brake system.
5. Explain the proper use of engine brakes.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Bulletin No. 3379079-92 Cummins Engine Shop Manual.* Columbus, IN: Cummins Engine Company, Inc., 1977

B. Forier, Louis C. *Motor Truck and Diesel Repair Manual.* 33rd ed. New York, NY: Motor, 1980.

C. *Service Manual: 3406 Engine.* Morton, IL: Caterpillar Tractor Company, 1979.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Filmstrip

1. *Caterpillar Retarder,* (SESU 1404)
   Literature Order Section
   P.O. Box 5319
   Morton, IL 61550

   (NOTE: You can also order from your nearest Caterpillar dealer.)

878

ENGINE BRAKES AND RETARDERS
UNIT IV-C

INFORMATION SHEET

I. **Terms and definitions**

A. Air suppressor — Stops air pulsations

B. Clutch switch — Disengages compression brake when clutch is depressed

C. Engine brake or retarder — Device used to convert the engine into a compressor or air pump, thus effectively slowing down the engine and braking the vehicle (Transparency 1)

D. Exhaust brake — Uses a valve in the exhaust which keeps the exhaust gases backed up in the exhaust manifold (Transparency 2)

E. Master piston — Supplies high pressure oil to slave piston

F. Pump switch — Disengages when clutch is depressed upon acceleration

G. Slave piston — Operates exhaust valves

II. **Jacobs engine brake operation** (Transparencies 3 and 4)

A. Driver operates an electrical switch.

B. A solenoid valve permits lubricating oil to flow under pressure through the slave piston control valve to both the master piston and slave piston.

C. Oil pressure causes the master piston to move down, coming to rest on the injector rocker arm adjusting screw.

(NOTE: Some systems do not have rocker arms.)

D. The injector rocker arm adjusting screw begins upward travel forcing the master piston upward and creating a high pressure oil flow to the slave piston.

E. The ball check valve in the control valve imprisons high pressure oil in the master-slave piston system.

F. The slave piston under the influence of high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.

G. Compressed air escapes into the atmosphere, completing a compression braking cycle; the piston starts down on the power stroke and all valves are closed thus creating a vacuum.

INFORMATION SHEET

III. **Troubleshooting the Jacobs engine brake**

A. Engine fails to start — Solenoid valves stuck in the open position

B. Drop in engine lube oil pressure

1. Oil inlet supply seal missing or damaged
2. Upper solenoid valve seal missing or damaged
3. Fuel line leakage

(NOTE: This applies only to Detroit diesel engine.)

C. One or two cylinders fail to brake

1. Slave piston control valve stuck in "Off" position
2. Slave piston control valve failure
3. Slave piston adjustment incorrect
4. Engine brake housing oil connector or seals leaking

D. Solenoids won't control brake operation — Center solenoid valve seal missing or damaged

E. Solenoids will not energize

1. Blown fuse
2. Automatic switches fail to close
3. Incorrect electrical power source

F. Engine brake slow to operate

1. Lube oil cold and/or too thick
2. Lower solenoid valve seal missing or damaged
3. Solenoid valve filter screen clogged
4. Control valves binding in housing
5. Switch operation sluggish
6. Incorrect adjustments

INFORMATION SHEET

G. One or more cylinders fail to stop braking or engine stalls

1. One or more slave piston control valves stuck in "On" position
2. Solenoid valve sticking in "On" position
3. Center solenoid valve seal missing or damaged
4. Solenoid valve exhaust plugged
5. Switch stuck in "On" position or misadjusted
6. Buffer switch set too tight

IV. **Advantages of the Jacobs engine brake**

A. Brake lining and brake drum life is extended up to five times that obtained without the Jacobs engine brake.

B. The ability of the brake to maintain engine operating temperatures on down hill grades and the possibility that the frequency of valve setting can be reduced, all lend a hand in lowering overall maintenance costs of diesel vehicle operation.

C. A minimum amount of labor is required for installation with very little service needed.

D. The elimination of continual braking with vehicle service brakes and the resulting reduction of heat add considerably to tire life and wear.

E. Shorter round trip schedules can be obtained through use of the engine brake, providing valuable extra hours.

V. **Operation of the BrakeSaver** (Transparency 5)

A. The rotor is fastened to and turns with the engine crankshaft; the rotor has pockets on the outer circumference of both sides and four holes to permit equal flow to both sides of the rotor. (Transparencies 5 and 6)

B. The housing and stator are fastened to the flywheel housing and cannot turn; both have pockets on their inside surfaces in alignment with the pockets in the motor. (Transparencies 5 and 6)

C. The rotor turns in the compartment made by the stator and the BrakeSaver housing.

D. When housing is in operation, engine oil comes in near center from a passage at bottom of the housing. (Transparency 6)

INFORMATION SHEET

E. The rotor turns with crankshaft and throws this oil outward; the shape of the rotor pockets sends it into the pockets of the stator and housing.

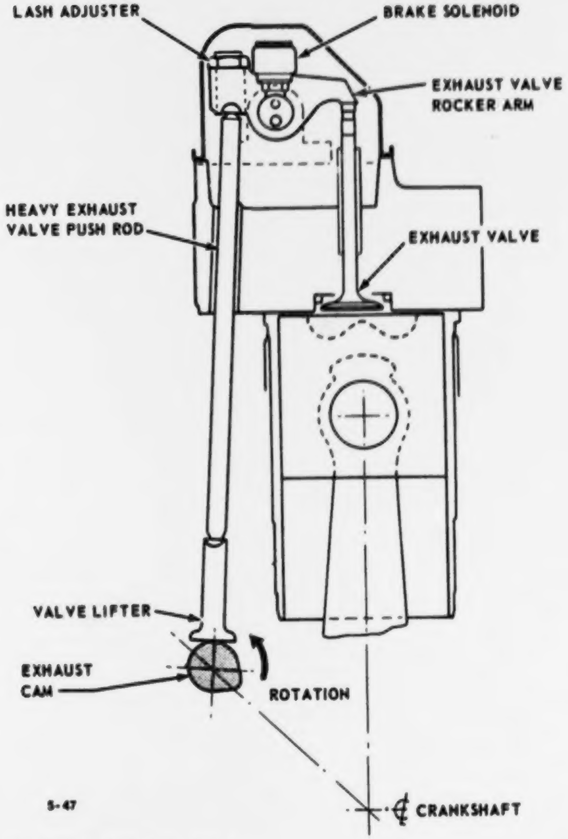
F. As the rotor turns and oil flows around the BrakeSaver compartment, it takes the shape of a spiral.

G. The oil flow is constantly cut by the vanes of the rotor; this cutting action gives resistance to the oil.

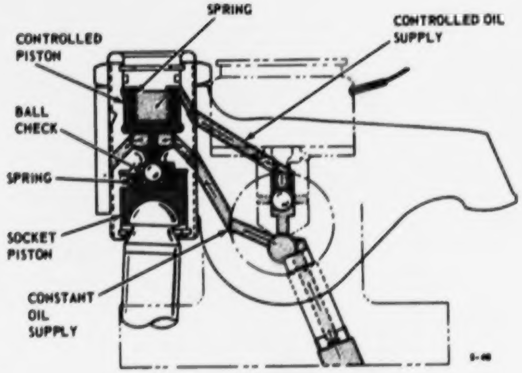
H. When BrakeSaver is in operation, the level of braking can be controlled by the inlet oil pressure, since the amount of oil is cut by the rotor vanes.

I. When BrakeSaver is not in operation, the inlet passage to the rotor is closed by the control valve, and there is no oil in the BrakeSaver compartment.

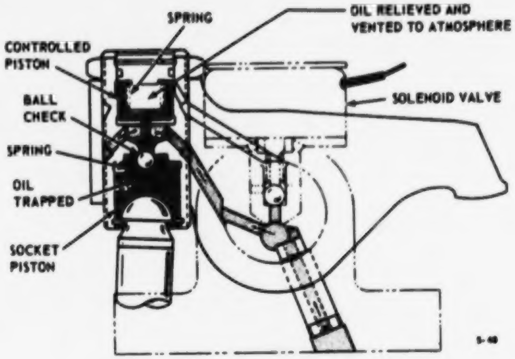
Dynatard Engine Brake on a Mack Diesel


LASH ADJUSTER
BRAKE SOLENOID
EXHAUST VALVE ROCKER ARM
HEAVY EXHAUST VALVE PUSH ROD
EXHAUST VALVE
VALVE LIFTER
EXHAUST CAM
ROTATION
℄ CRANKSHAFT
5-47

(Courtesy of Mack Trucks, Inc.)

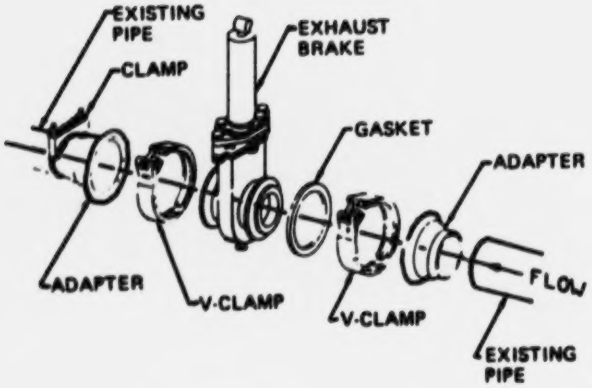

SPRING
CONTROLLED PISTON
CONTROLLED OIL SUPPLY
BALL CHECK
SPRING
SOCKET PISTON
CONSTANT OIL SUPPLY

OIL FLOW THROUGH LASH ADJUSTER BRAKE "OFF"

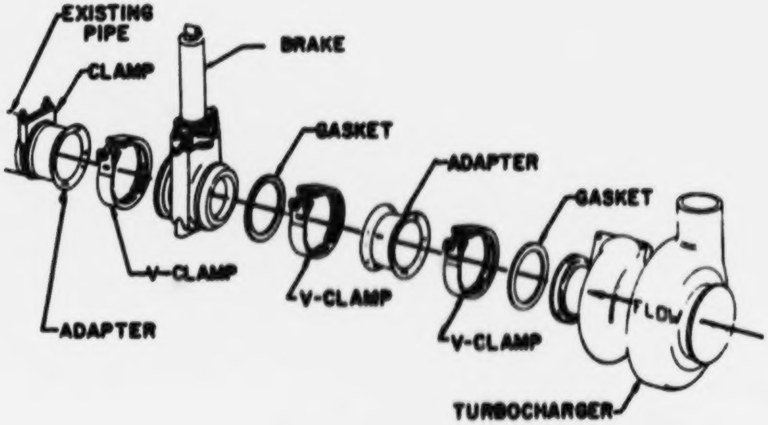

SPRING
OIL RELIEVED AND VENTED TO ATMOSPHERE
CONTROLLED PISTON
SOLENOID VALVE
BALL CHECK
SPRING
OIL TRAPPED
SOCKET PISTON

OIL FLOW THROUGH LASH ADJUSTER BRAKE "ON"

Williams Blue Ox Engine Brake


EXISTING PIPE
CLAMP
EXHAUST BRAKE
GASKET
ADAPTER
ADAPTER
V-CLAMP
V-CLAMP
FLOW
EXISTING PIPE

NON-TURBOCHARGED ENGINES


EXISTING PIPE
CLAMP
BRAKE
GASKET
ADAPTER
GASKET
V-CLAMP
ADAPTER
V-CLAMP
V-CLAMP
FLOW
TURBOCHARGER

TURBOCHARGED ENGINES

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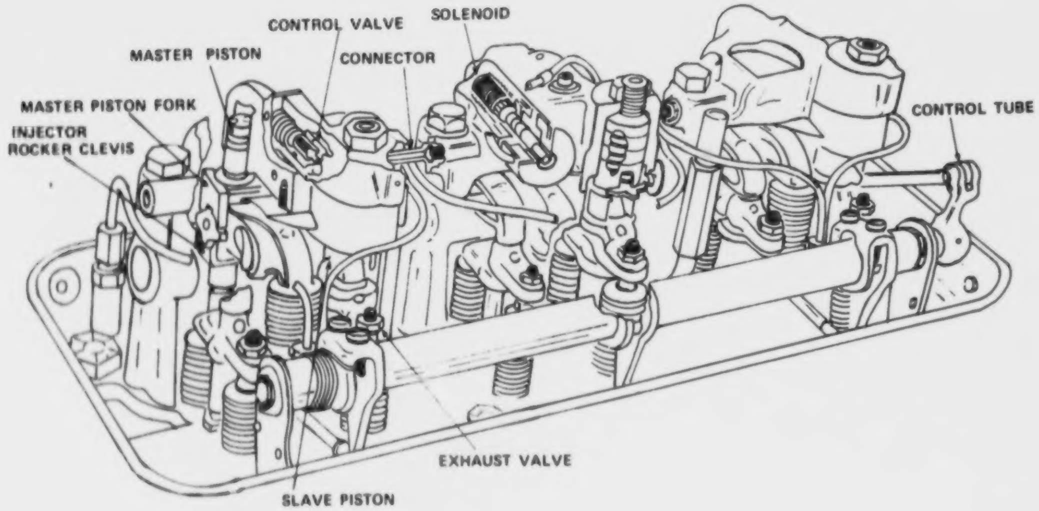
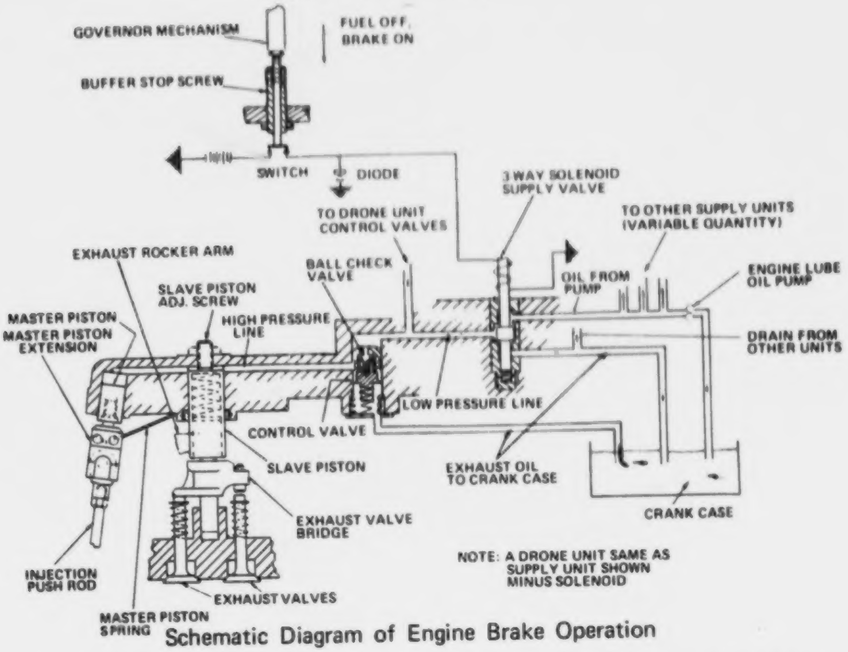
Jacobs Engine Brake on a Detroit Diesel


CONTROL VALVE
SOLENOID
MASTER PISTON
CONNECTOR
MASTER PISTON FORK
INJECTOR ROCKER CLEVIS
CONTROL TUBE
EXHAUST VALVE
SLAVE PISTON

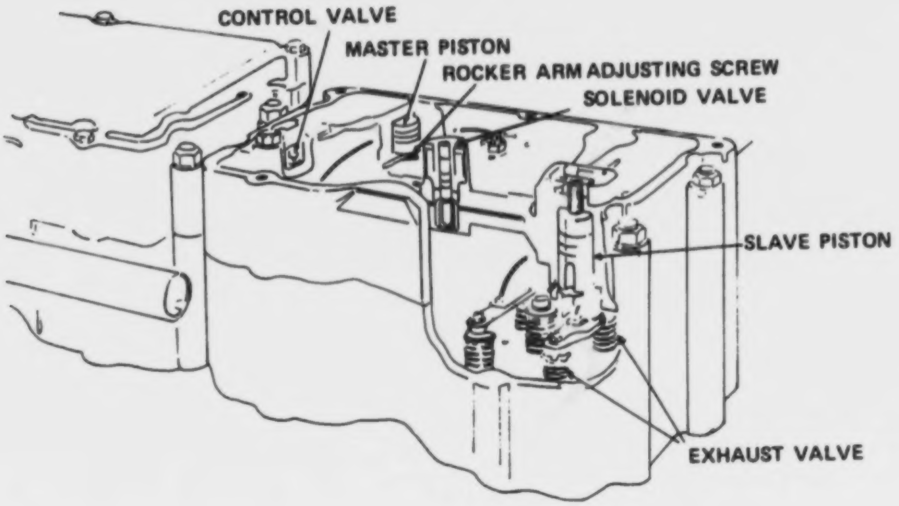
Engine Brake Cutaway


GOVERNOR MECHANISM
FUEL OFF, BRAKE ON
BUFFER STOP SCREW
SWITCH
DIODE
3 WAY SOLENOID SUPPLY VALVE
TO DRONE UNIT CONTROL VALVES
TO OTHER SUPPLY UNITS (VARIABLE QUANTITY)
EXHAUST ROCKER ARM
BALL CHECK VALVE
OIL FROM PUMP
ENGINE LUBE OIL PUMP
SLAVE PISTON ADJ. SCREW
MASTER PISTON
MASTER PISTON EXTENSION
HIGH PRESSURE LINE
DRAIN FROM OTHER UNITS
LOW PRESSURE LINE
CONTROL VALVE
SLAVE PISTON
EXHAUST OIL TO CRANK CASE
CRANK CASE
EXHAUST VALVE BRIDGE
NOTE: A DRONE UNIT SAME AS SUPPLY UNIT SHOWN MINUS SOLENOID
INJECTION PUSH ROD
EXHAUST VALVES
MASTER PISTON SPRING

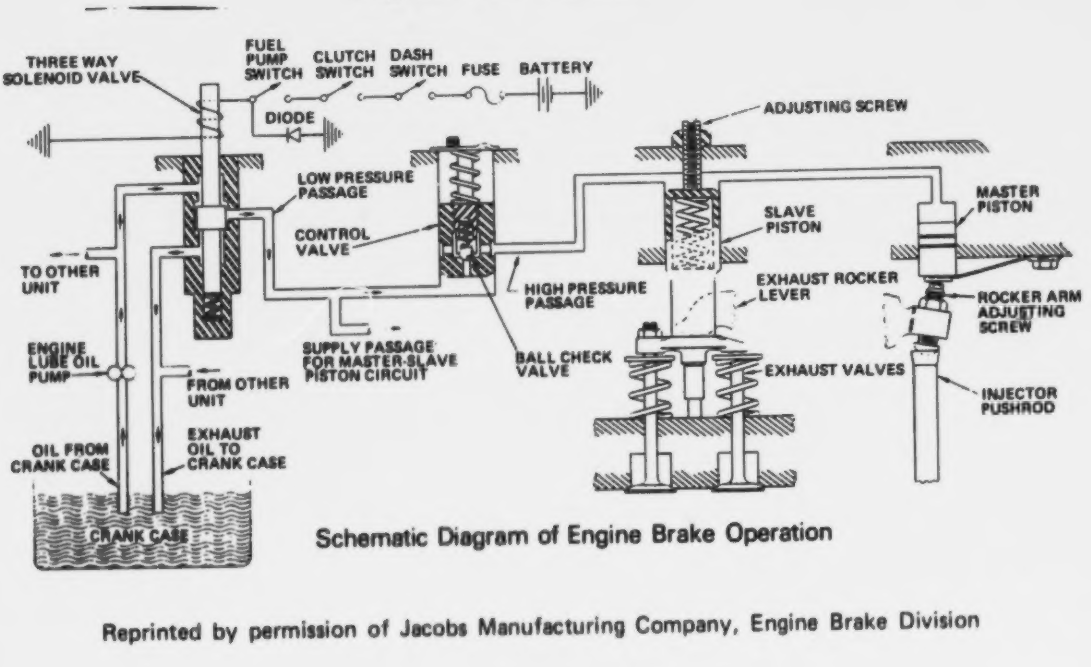
Schematic Diagram of Engine Brake Operation

Reprinted by permission of Jacobs Manufacturing Company, Engine Brake Division

Jacobs Engine Brake on a Cummins (NH) Diesel


CONTROL VALVE
MASTER PISTON
ROCKER ARM ADJUSTING SCREW
SOLENOID VALVE
SLAVE PISTON
EXHAUST VALVE

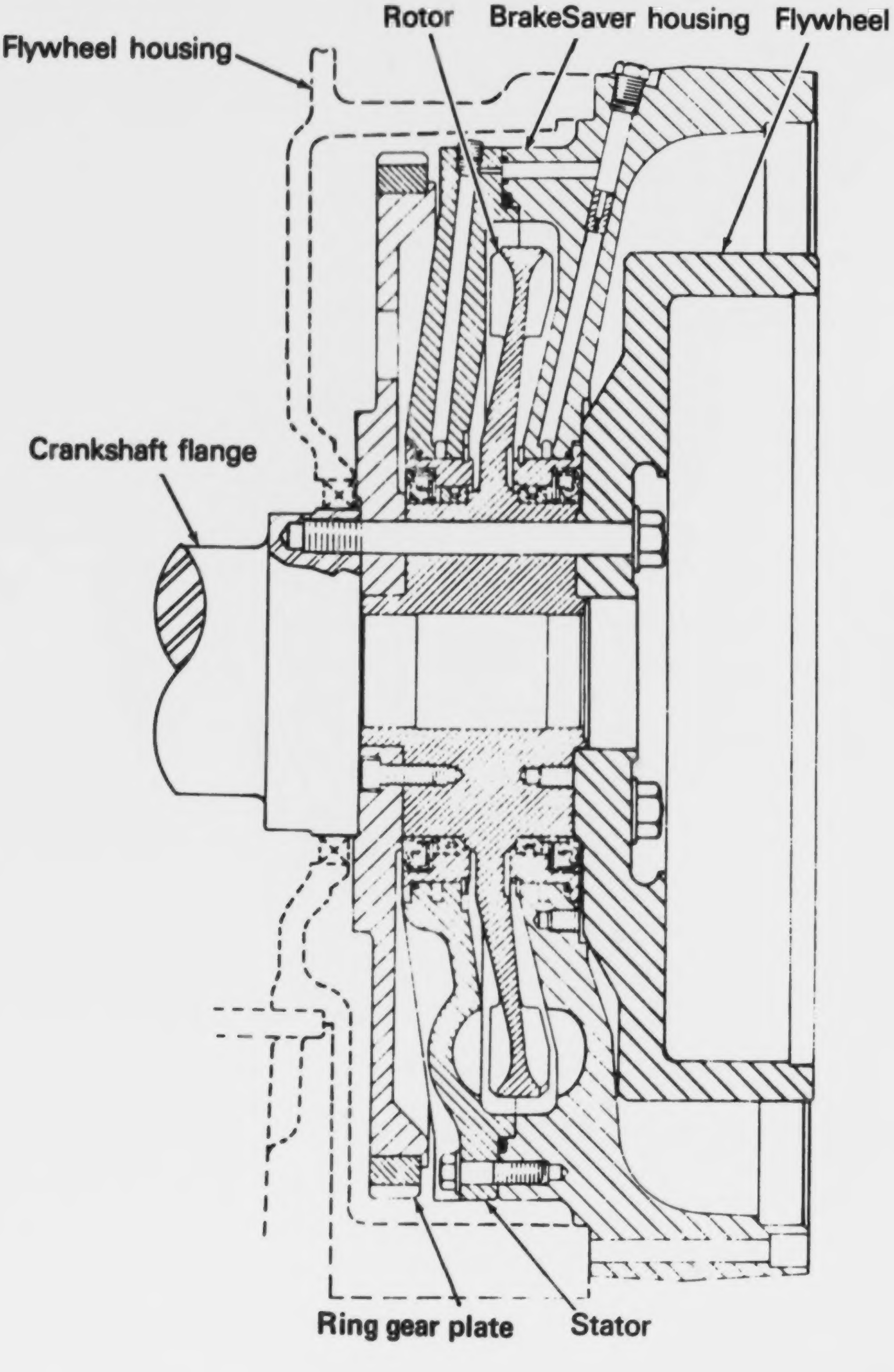
Engine Brake Cutaway


THREE WAY SOLENOID VALVE
FUEL PUMP SWITCH
CLUTCH SWITCH
DASH SWITCH
FUSE
BATTERY
DIODE
ADJUSTING SCREW
LOW PRESSURE PASSAGE
CONTROL VALVE
SLAVE PISTON
MASTER PISTON
TO OTHER UNIT
HIGH PRESSURE PASSAGE
EXHAUST ROCKER LEVER
ROCKER ARM ADJUSTING SCREW
ENGINE LUBE OIL PUMP
SUPPLY PASSAGE FOR MASTER-SLAVE PISTON CIRCUIT
BALL CHECK VALVE
EXHAUST VALVES
FROM OTHER UNIT
INJECTOR PUSHROD
OIL FROM CRANK CASE
EXHAUST OIL TO CRANK CASE
CRANK CASE

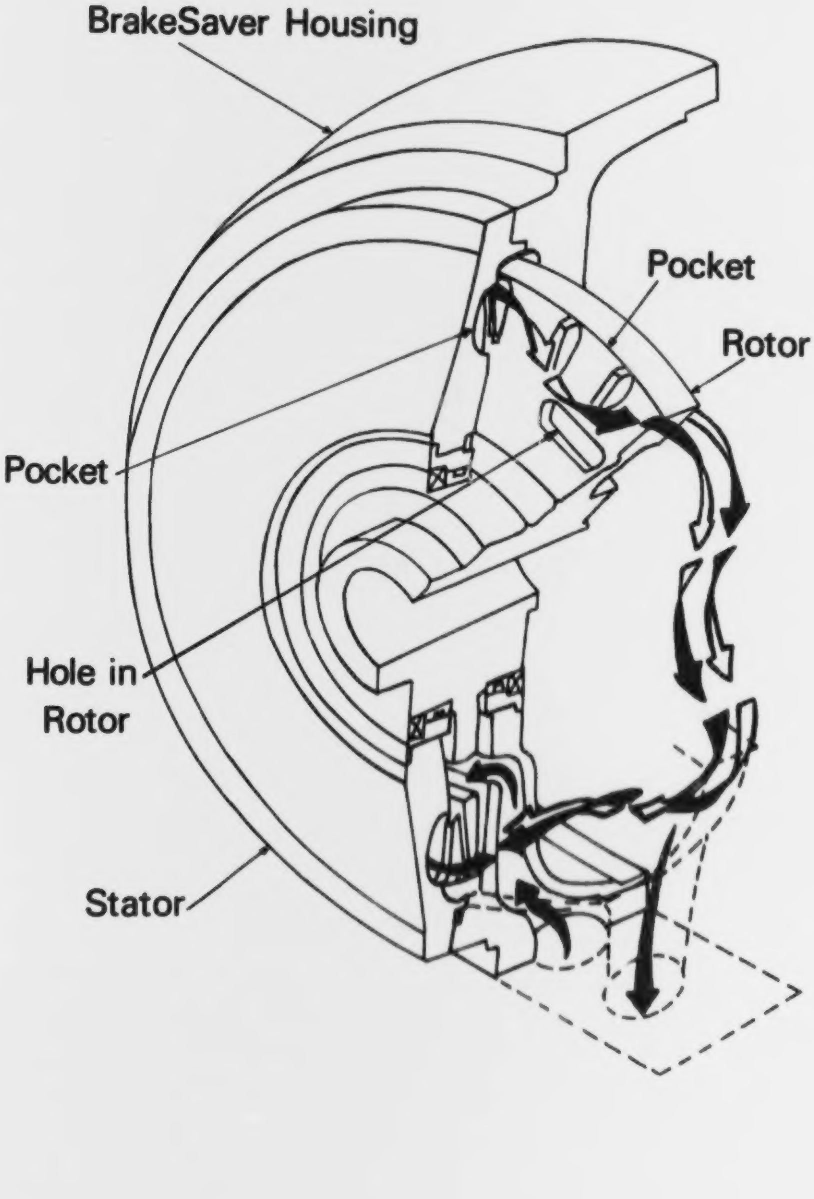
Schematic Diagram of Engine Brake Operation

Reprinted by permission of Jacobs Manufacturing Company, Engine Brake Division

BrakeSaver On A Caterpillar Diesel


Rotor
BrakeSaver housing
Flywheel
Flywheel housing
Crankshaft flange
Ring gear plate
Stator

Oil Flow Through A BrakeSaver


BrakeSaver Housing
Pocket
Rotor
Pocket
Hole in Rotor
Stator

890

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #1 — ADJUST A JACOBS ENGINE BRAKE ON A DETROIT DIESEL

A. Tools and materials

1. Basic hand tools
2. Appropriate service manual
3. Clean shop towels
4. Safety glasses
5. Detroit diesel engine with Jacobs engine brake

B. Procedure

(CAUTION: Follow all shop safety procedures.)

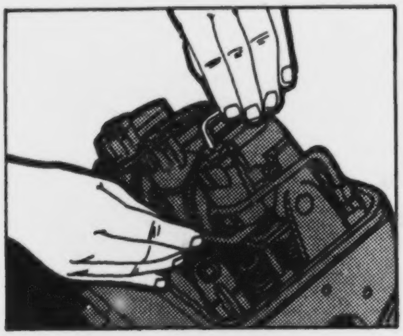
1. Adjust slave piston model 20.
   a. Loosen and back off locknut.
   b. Use a feeler gauge and back off slave piston adjusting screw until piston spring lets go of adjusting screw.

      (NOTE: Valve piston will move up into housing under influence of its spring until it seats in its bore, removing spring load from adjusting screw.)
   c. Bring the engine to normal operating temperature.
   d. Set engine idle to 550 rpm.

JOB SHEET #1

e. Turn adjusting screw down slowly until slave piston contacts the cross-head as indicated by the twitch in the handle of the allen wrench. (Figure 1)

FIGURE 1



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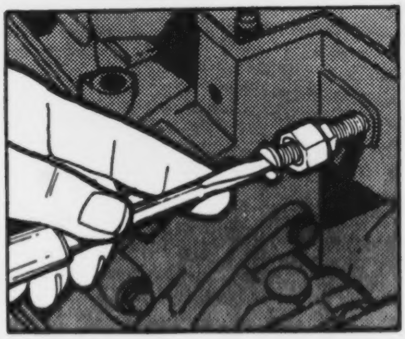
(NOTE: Do not attempt to make this adjustment by holding the locknut and turning the adjusting screw through both the locknut and the brake housing.)

f. Back the adjusting screw out exactly 1/2 turn and tighten locknut.

2. Adjust buffer screw models 53A and 71. (Figure 2)

FIGURE 2



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a. Start the engine.

b. Adjust the buffer screw to stop governor hunting at idle speed.

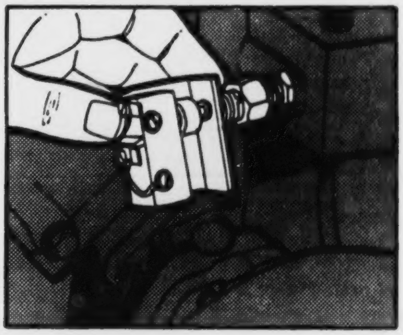
c. Do not increase engine speed above normal idle by forcing buffer screw past the point where governor hunt has been eliminated.

JOB SHEET #1

d. Tighten lock nut.

e. Attach buffer switch to buffer screw and position switch to clear other engine components. (Figure 3)

FIGURE 3



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ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #2 — TROUBLESHOOT A CATERPILLAR BRAKESAVER

A. Tools and materials

1. Basic hand tools
2. Appropriate service manual
3. Clean shop towels
4. Safety glasses
5. Caterpillar engine manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Clunk check (check for free movement of the valve spool)
    a. Run the engine until the truck air system reaches its maximum pressure then stop the engine.
    b. Switch the BrakeSaver to full "On."
    c. Switch the BrakeSaver to "Off." Listen for the clunk (sound) of the spool in the control valve.
    d. If the clunk is not heard at the control valve, remove and disassemble the control valve. Inspect the valve for any of the following:
        1) Damaged valve body
        2) Damaged or worn spring in valve spool
        3) Damaged or worn valve spool
        4) Damaged or worn O-ring seals or diaphragm in control valve
        5) Closed holes in the side of the valve spool

JOB SHEET #2

2. Complete pull-down rpm check.

   (NOTE: The engine must produce rested horsepower for this test to be accurate.)

   a. Apply the vehicle braker.

   b. Place the transmission in neutral.

   c. Operate engine at high idle.

      (NOTE: Accelerator should be on the floor.)

   d. Record the engine rpm.

   e. Switch the BrakeSaver to the full "On" position.

   f. Record the engine rpm with BrakeSaver on.

   g. Make sure the BrakeSaver is full "On," and the rpm should drop from 125 to 175.

      (NOTE: If rpm drops between 125 and 175, the BrakeSaver is operating properly. If the drop is less than 125 rpm, go to Step h. If the drop is more than 175rpm, go to Step i.)

   h. Check for an rpm drop of less than 125 rpm; BrakeSaver is defective if this happens.

   i. If the rpm drops more than 175 rpm, check the air pressure to the BrakeSaver control valve.

      (NOTE: The pressure should be no more than 50 psi.)

      (CAUTION: Do not run the engine at high rpm with the BrakeSaver on for more than 15 seconds at a time. Let the engine run at low idle with the BrakeSaver off for five minutes to prevent overheating the engine cooling system)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #3 — REMOVE A BRAKESAVER ON A CATERPILLAR DIESEL ENGINE

A. Tools and materials

1. Basic hand tools
2. Appropriate service manual
3. Shop towels
4. Safety glasses
5. Caterpillar engine with BrakeSaver

B. Procedure

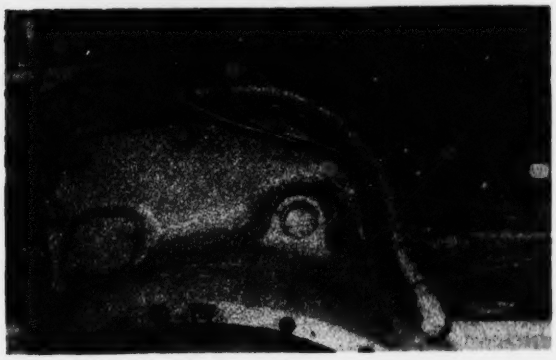
(CAUTION: Follow all shop safety procedures.)

1. Remove transmission from vehicle as specified in manual.

   (NOTE: When removing transmission be sure the ground cable is removed from the battery and a tag is on the starting switch.)

2. Disconnect the lubrication oil line from the fitting at the top of BrakeSaver housing. (Figure 1)

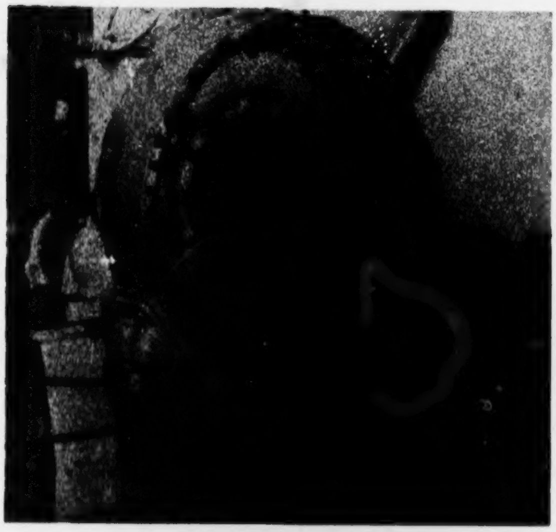
FIGURE 1



JOB SHEET #3

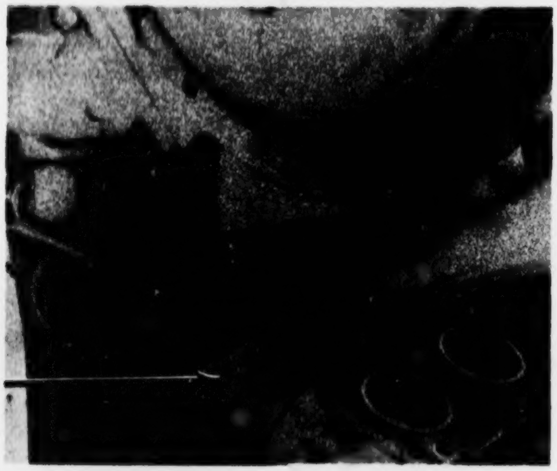
3. Disconnect the oil line at the bottom of the BrakeSaver housing. (Figure 2)

FIGURE 2


Two Short Bolts
Oil Line
Oil Manifold
Two Long Bolts

4. Remove the two short bolts and two longer bolts that hold oil manifold to BrakeSaver housing, and remove the manifold from the BrakeSaver control valve. (Figures 2 and 3)

FIGURE 3



(NOTE: The two longer bolts from the manifold can be used as forcing screws to remove the BrakeSaver from the flywheel housing.)

JOB SHEET #3

5. Remove the O-ring seals from the manifold. (Figure 4)

FIGURE 4

6. Install an eye bolt in the top of the BrakeSaver housing and fasten a hoist; install tool on the BrakeSaver housing and rotor. (Figure 5)

FIGURE 5

Bolts
Tooling Bar
BrakeSaver Housing
Long Manifold Bolts

(NOTE: The tool holds the BrakeSaver housing and rotor assembly together while removing; this prevents damage to the rotor rings and seals.)

JOB SHEET #3

7. Remove bolts that hold BrakeSaver housing to the flywheel housing. (Figure 6)

FIGURE 6

(NOTE: Use long bolts from manifold as forcing screws, and tighten the bolts evenly to remove the BrakeSaver housing from the flywheel housing.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #4 — DISASSEMBLE A BRAKESAVER

A. Tools and materials

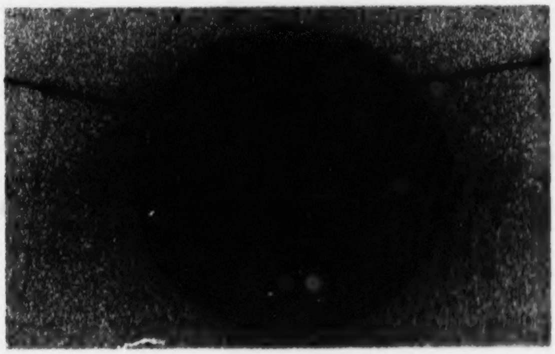
1. Basic hand tools
2. Appropriate service manual
3. Puller set
4. Shop towels
5. Safety glasses
6. BrakeSaver assembly

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove the tool holding the BrakeSaver housing and rotor together.
2. Remove bolts from gear plate and remove the plate. (Figure 1)

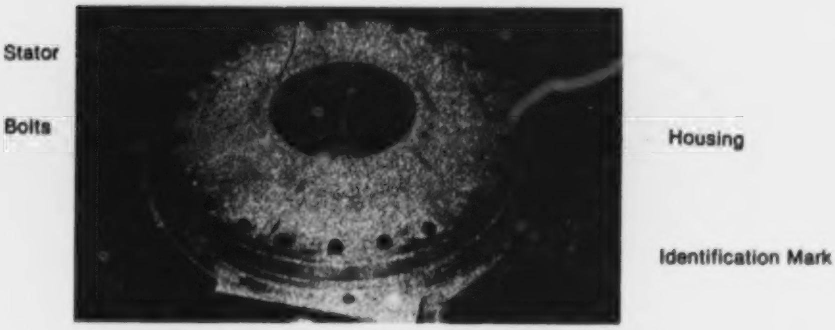
FIGURE 1



JOB SHEET #4

3. Make identification as to the location of stator with housing, and remove bolts and stator. (Figure 2)

FIGURE 2


Stator
Bolts
Housing
Identification Mark

4. Turn the stator over and remove spiral ring. (Figure 3)

FIGURE 3

Spiral Ring

5. Turn the stator over again and remove sleeve assembly, O-ring seal, and lip type seal from the sleeve. (Figure 4)

FIGURE 4

O-ring Seal
Sleeve Assembly
Lip Type Seal

JOB SHEET #4

6. Remove O-ring seal and the six smaller O-ring seals from the oil holes on the housing. (Figure 5)

FIGURE 5

Seal Ring
O-ring Seal
Rotor Assembly

7. Remove rotor assembly and seal ring from both sides of the rotor. (Figure 5)

8. Remove carrier and wear sleeve with puller from both sides of the rotor. (Figure 6)

FIGURE 6

Puller
Carrier
Wear Sleeve

9. Remove spiral ring. (Figure 7)

FIGURE 7

Spiral Ring

JOB SHEET #4

10. Turn the housing over and remove sleeve assembly; remove the lip type seal and O-ring seal from the sleeve. (Figure 8)

FIGURE 8

O-ring Seal
Sleeve Assembly

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #5 — ASSEMBLE A BRAKESAVER

A. Tools and materials

1. Basic hand tools
2. Appropriate service manual
3. Shop towels
4. Seal installer set
5. Safety glasses
6. BrakeSaver assembly

B. Procedure

(CAUTION: Follow all shop safety procedures.)

(NOTE: Inspect the O-ring seals for damage and make replacements if needed.)

1. Install O-ring seal on sleeve. (Figure 1)

FIGURE 1

Sleeve
O-ring Seal

(NOTE: Put clean oil on the O-ring seals while installing.)

2. Install the sleeve in the BrakeSaver housing, making sure the notch in the sleeve is aligned with the notch in the housing; install the dowel.

(CAUTION: Make certain there is clearance behind the spiral ring when it is correctly installed.)

JOB SHEET #5

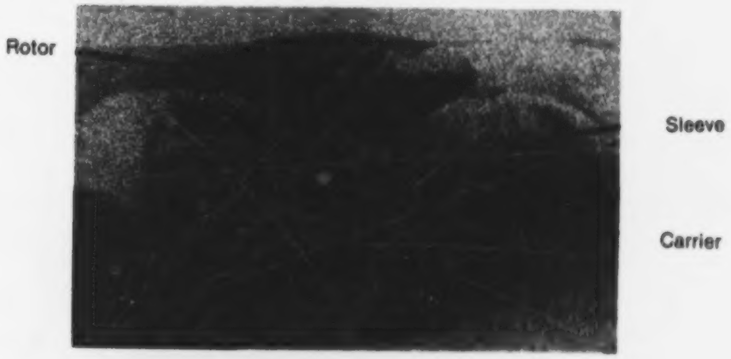
3. Turn the housing over and install the spiral ring that holds the sleeve in the housing.

4. Heat the carriers and the wear sleeves to a maximum temperature of 300°F.

   (NOTE: Make sure the carrier is at bottom on the rotor and sleeve is against the carrier.)

5. Install carrier on each side of rotor and install wear sleeve with the taper edge of sleeve in the "Up" position. (Figure 2)

   FIGURE 2



6. Install a seal ring in each of the carriers. (Figure 3)

   FIGURE 3

BrakeSaver Housing
Seal Ring

7. Install the rotor assembly in BrakeSaver housing. (Figure 3)

JOB SHEET #5

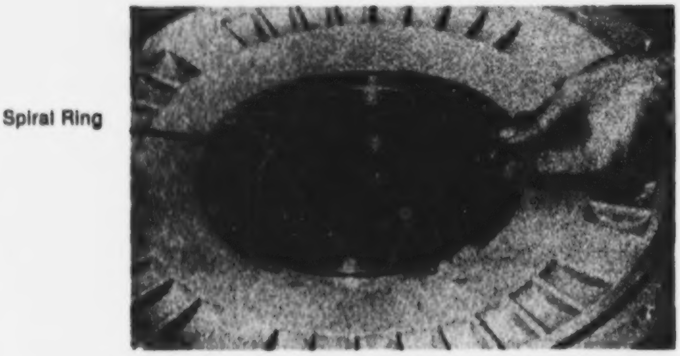
8. Install O-ring seal on the sleeve, and install sleeve in the stator; make alignment of the notch in the sleeve with the dowel in the stator. (Figure 4)

FIGURE 4

O-ring Seal
Sleeve

9. Turn the stator over and install spiral ring that holds the sleeve in the stator. (Figure 5)

FIGURE 5


Spiral Ring

10. Install O-ring seal and six smaller seals for the oil holes on the housing. (Figure 6)

FIGURE 6

O-ring Seal
Smaller Seals

JOB SHEET #5

11. Put the stator in the correct location on the housing with respect to the identification put on at removal; make sure the oil holes in the stator and the housing are in alignment.

12. Install the bolts that hold stator to the housing, and tighten to specification torque.

13. Follow the steps below when installing the lip type seals.

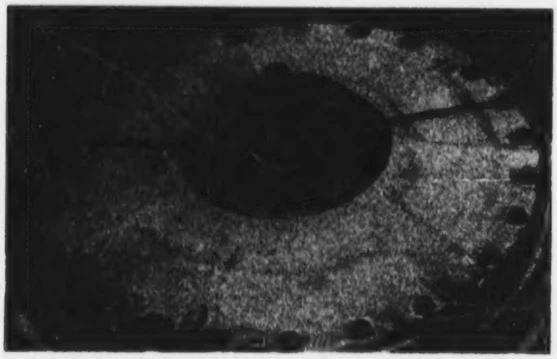
    a. Put clean engine oil on the lip of the seals.

    b. Put the pilot inside the seal, and install pilot and seal with the inside taper of the pilot against the wear sleeve.

       (NOTE: The lip of the seal must be toward the rotor.)

    c. Install locator and bolts on the rotor. (Figure 7)

FIGURE 7



    d. Put ring over the locator and plate on the ring. (Figure 8)

FIGURE 8

Nut
Pusher Plate
Ring

JOB SHEET #5

e. Tighten nut on the locator until tooling is at bottom. (Figure 8)

14. Install gear plate and the bolts that hold it on the rotor. (Figure 9)

FIGURE 9

Gear Plate

15. Turn the housing over carefully and repeat Step 13 to install the other lip type seal on the rotor.

16. Install tooling bar to the rotor and the housing. (Figure 10)

FIGURE 10

Tooling Bar

(NOTE: Tooling bar will prevent damage to the rotor seals and rings at installation.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #6 — INSTALL A BRAKESAVER

A. Tools and materials

1. Basic hand tools
2. Appropriate service manual
3. Shop towels
4. Safety glasses
5. BrakeSaver assembly

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Install tooling on the BrakeSaver housing and rotor. (Figure 1)

FIGURE 1

Dowel
Guide Pins
BrakeSaver Housing
Tooling Bar

(NOTE: Tooling plate holds the BrakeSaver housing and rotor assembly together at installation; this prevents damage to the rotor rings and seals.)

2. Install eye bolt in the top of the BrakeSaver housing and fasten a hoist. (Figure 1)
3. Install two guide pins in the crankshaft, as shown, making sure dowel is in alignment with the dowel hole in the rotor assembly. Put BrakeSaver housing in position in the flywheel housing. (Figure 1)
4. Install the bolts that hold BrakeSaver housing to the flywheel housing, and remove the tooling bar and guide pins.

JOB SHEET #6

5. Connect the oil line to fitting. (Figure 2)

FIGURE 2

Oil Line Fitting
O-ring Seals
Oil Manifold

6. Inspect the O-ring seals for damage and replace, if needed; install O-rings and put clean oil on the O-ring seals. (Figure 2)

7. Install manifold into the BrakeSaver control valve, and install the bolts that hold the manifold to the BrakeSaver housing. (Figure 2)

8. Connect BrakeSaver lubrication oil line to the fitting in the BrakeSaver housing. (Figure 3)

FIGURE 3

Oil Line Fitting

9. Install flywheel to BrakeSaver.

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #7 — INSTALL A JACOBS ENGINE BRAKE ON A MACK DIESEL

A. Tools and materials

1. Basic hand tools
2. Mack service manual
3. Clean shop towels
4. Torque wrench
5. Feeler gauge
6. Safety glasses

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Remove rocker arm shaft assemblies from engine, and note the location of all exhaust valve rocker levers. (Figure 1)

FIGURE 1

JOB SHEET #7

2. Replace exhaust valve rocker arm adjusting screws with new adjusting screws from kit. (Figure 2)

FIGURE 2

(CAUTION: To provide proper clearance between rocker arm and underside of brake housing, gauge rocker arm and grind if necessary in area shown in Figure 3.)

3. Replace rocker arm shaft set screws in top face of rocker pedestals over cylinders #1 and #4 with Jacobs oil supply screws. (Figure 3)

FIGURE 3

JOB SHEET #7

4. Replace exhaust valve stem caps over all exhaust valve stems. (Figure 4)

FIGURE 4

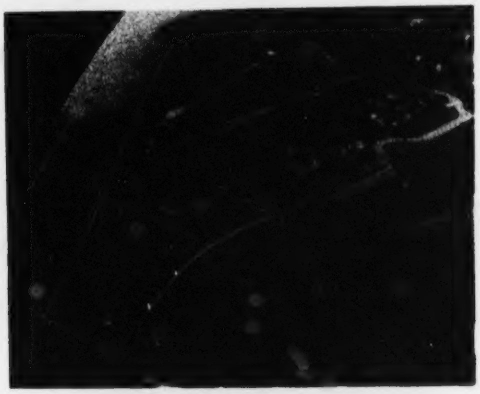
5. Replace rocker assemblies and new O-rings, if necessary, under pedestals; start, but do not tighten, the six short holddown cap screws to locate the rocker shaft brackets, making sure push rods are in their respective sockets. (Figure 5)

FIGURE 5

JOB SHEET #7

6. Install engine brake housing. (Figure 6)

FIGURE 6



7. Insert six long holddown cap screws connecting brake housing and rocker arm shaft assemblies to cylinder heads, and torque to specification. (Figure 7)

FIGURE 7

JOB SHEET #7

8. Before starting engine, adjust intake and exhaust valves as instructed by *Mack Operation and Maintenance Manual* for cold static clearance.

9. Back off all engine brake slave piston adjusting screws ½" above top face of housing.

10. Proceed to run engine until normal hot idle temperature for valve adjustment is reached.

11. Shut engine down and make hot valve adjustment.

    (NOTE: Valve adjustment should **NOT** be attempted with engine running.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

JOB SHEET #8 — ADJUST SLAVE PISTON OF A JACOBS ENGINE BRAKE ON A MACK DIESEL

A. Tools and materials

1. Basic hand tools
2. Mack service manual
3. Clean shop towels
4. Torque wrench
5. Feeler gauge
6. Safety glasses

B. Procedure

(CAUTION: To insure maximum brake operating efficiency and to prevent engine damage by piston to valve contact, the following instructions must be followed carefully. Follow all shop safety procedures.)

1. Close exhaust valves fully and turn slave piston adjusting screw inward until zero clearance is established between slave piston feet and exhaust valve stem cap.
2. Back out adjusting screw ¾ turn to establish proper operating clearance. (Figure 1)

FIGURE 1

(CAUTION: Do not turn adjusting screw far enough to open exhaust valve.)

JOB SHEET #8

3. Hold adjusting screw with screwdriver and tighten jam nut.

   (NOTE: The above adjustment may be made with the engine hot or cold, but it must be shut down.)

4. Connect solenoid valve leads to terminals on inside of cylinder head cover spacers. (Figure 2)

   FIGURE 2

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #1 — ADJUST A JACOBS ENGINE BRAKE ON A DETROIT DIESEL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted slave piston.	______	______
3. Adjusted buffer screw.	______	______
4. Checked in/put away tools and materials.	______	______
5. Cleaned the work area.	______	______
6. Used proper tools correctly.	______	______
7. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
8. Practiced safety rules throughout procedure.	______	______
9. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Engine brake operates correctly after adjustment				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #2 — TROUBLESHOOT A CATERPILLAR BRAKESAVER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Brought air system up to maximum.	______	______
3. Switched BrakeSaver to full "On."	______	______
4. Switched the BrakeSaver to "Off."	______	______
5. Determined condition of the control valve.	______	______
6. Checked pull-down rpm.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Determined if control valve was operating	4	3	2	1
Determined condition of BrakeSaver	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #3 — REMOVE A BRAKESAVER ON A CATERPILLER DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed transmission.	______	______
3. Disconnected oil lines.	______	______
4. Removed manifold from BrakeSaver.	______	______
5. Removed bolts from BrakeSaver.	______	______
6. Removed BrakeSaver.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Removed BrakeSaver correctly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #4 — DISASSEMBLE A BRAKESAVER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Removed bolts from gear plate.	______	______
3.	Marked stator locations.	______	______
4.	Removed spiral ring.	______	______
5.	Removed sleeve assembly.	______	______
6.	Removed O-ring seals.	______	______
7.	Removed rotor assembly and seal rings.	______	______
8.	Removed carrier and wear sleeves.	______	______
9.	Removed sleeve assembly and lip seal.	______	______
10.	Checked in/put away tools and materials.	______	______
11.	Cleaned the work area.	______	______
12.	Used proper tools correctly.	______	______
13.	Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
14.	Practiced safety rules throughout procedure.	______	______
15.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Disassembled Brake-Saver correctly				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #5 — ASSEMBLE A BRAKESAVER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Installed O-ring seals on sleeve.	______	______
3. Installed sleeve.	______	______
4. Installed spiral ring.	______	______
5. Installed carrier and wear sleeve.	______	______
6. Installed seal rings.	______	______
7. Installed rotor in housing.	______	______
8. Installed O-rings on sleeve.	______	______
9. Installed stator in correct location.	______	______
10. Installed stator bolts and torqued.	______	______
11. Installed gear plate.	______	______
12. Installed tool bar to rotor.	______	______
13. Checked in/put away tools and materials.	______	______
14. Cleaned the work area.	______	______
15. Used proper tools correctly.	______	______
16. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
17. Practiced safety rules throughout procedure.	______	______
18. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Assembled BrakeSaver correctly				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #6 — INSTALL A BRAKESAVER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Installed tooling on BrakeSaver housing.	______	______
3. Installed eye bolt on housing.	______	______
4. Installed two guide pins.	______	______
5. Installed bolts to housing.	______	______
6. Connected oil lines.	______	______
7. Installed manifold to control valve.	______	______
8. Installed flywheel.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #6 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Installed BrakeSaver correctly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #7 — INSTALL A JACOBS ENGINE BRAKE ON A MACK DIESEL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Removed rocker arm shaft.	______	______
3. Replaced exhaust valve rocker adjusting screw.	______	______
4. Replaced rocker arm shaft set screws.	______	______
5. Replaced exhaust valve stem caps.	______	______
6. Replaced rocker assemblies.	______	______
7. Installed engine brake housing.	______	______
8. Installed and torqued six long holddown bolts.	______	______
9. Adjusted valves.	______	______
10. Checked in/put away tools and materials.	______	______
11. Cleaned the work area.	______	______
12. Used proper tools correctly.	______	______
13. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
14. Practiced safety rules throughout procedure.	______	______
15. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #7 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Rocker arm assembly is installed correctly	4	3	2	1
Valves are adjusted correctly	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

PRACTICAL TEST
JOB SHEET #8 — ADJUST SLAVE PISTON OF A JACOBS ENGINE BRAKE ON A MACK DIESEL

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted slave piston.	______	______
3. Tightened jam nut.	______	______
4. Connected solenoid valve leads.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #8 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Jacobs engine brake performs properly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

NAME ______________________________ SCORE ________________________

TEST

1. Match the terms related to engine brakes and retarders with the correct definitions.

______a. Uses a valve in the exhaust which keeps the exhaust gases backed up in the exhaust manifold

______b. Stops air pulsations

______c. Operates exhaust valves

______d. Disengages compression brake when clutch is depressed

______e. Supplies high pressure oil to slave piston

______f. Device used to convert the engine into a compressor or air pump, thus effectively slowing down the engine and braking the vehicle

______g. Disengages when clutch is depressed upon acceleration

1. Air suppressor
2. Clutch switch
3. Engine brake or retarder
4. Exhaust brake
5. Master piston
6. Pump switch
7. Slave piston

2. Select true statements concerning Jacobs engine brake operation by placing an "X" beside each operation.

______a. Driver operates an electrical switch.

______b. A solenoid valve permits lubricating oil to flow under pressure through the slave piston control valve to both the master piston and slave piston.

______c. Oil pressure causes the master slave piston to move down, coming to rest on the injector rocker arm adjusting screw.

______d. The injector rocker arm adjusting screw begins upward travel forcing the slave piston upward and creating a high pressure oil flow to the master piston.

______e. The ball check valve in the control valve imprisons high pressure oil in the master piston only.

______f. The slave piston under the influence of high pressure oil flow moves down, momentarily opening the exhaust valve, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.

______g. Compressed air escapes into the atmosphere, completing a compression braking cycle; the piston starts down on the power stroke and all valves are closed, thus creating a vacuum.

TEST

3. Complete the following list of troubleshooting procedures for the Jacobs engine brake.

   a. Engine fails to start — Solenoid valves stuck in the open position

   b. Drop in engine lube oil pressure

      1) Oil inlet supply seal ______________________________

      2) Upper solenoid valve seal missing or damaged

      3) Fuel line leakage

   c. One or two cylinders fail to brake

      1) Slave piston control valve stuck in "Off" position

      2) Slave piston control valve failure

      3) Slave piston adjustment incorrect

      4) Engine brake housing oil connector or seals leaking

   d. Solenoids won't control brake operation — ______________________

      ______________________ missing or damaged

   e. Solenoids will not energize

      1) Blown fuse

      2) Automatic switches ______________________________

      3) Incorrect electrical power source

   f. Engine brake slow to operate

      1) Lube oil cold and/or too thick

      2) Lower solenoid valve seal missing or damaged

      3) Solenoid valve filter screen clogged

      4) Control valves binding in housing

      5) Switch operation sluggish

      6) Incorrect adjustments

TEST

g. One or more cylinders fail to stop braking or engine stalls

1) One or more slave piston control valves stuck in ________________

2) Solenoid valve sticking in "On" position

3) Center solenoid valve seal missing or damaged

4) Solenoid valve exhaust plugged

5) Switch stuck in "On" position or misadjusted

6) Buffer switch set too tight

4. Complete the following list of advantages of the Jacobs engine brake.

a. Brake lining and brake drum life is ___________ that obtained without the Jacobs engine brake.

b. The ability of the brake to maintain engine operating temperatures on down hill grades and the possibility that the frequency of valve setting can be reduced, all lend a hand in ___________ of diesel vehicle operation.

c. A minimum amount of labor is required for installation with very little service needed.

d. The elimination of continual braking with vehicle service brakes and the resulting reduction of heat add considerably to ___________.

e. ___________ can be obtained through use of the engine brake, providing valuable extra hours.

5. Select true statements concerning the operation of the BrakeSaver by placing an "X" beside each statement that is true.

_____a. The rotor is fastened to and turns with the engine crankshaft; the rotor has pockets on the outer circumference of both sides, and four holes to permit equal flow to both sides of the rotor.

_____b. The housing and stator are fastened to the crankshaft and cannot turn; both have pockets on their inside surfaces in alignment with the pockets in the motor.

_____c. The rotor turns in the compartment made by the stator and the BrakeSaver housing.

_____d. When housing is in operation, engine oil comes in near center from a passage at bottom of the housing.

TEST

_____e. The rotor turns with crankshaft and throws this oil outward; the shape of the rotor pockets send it into the pockets of the stator and housing.

_____f. As the rotor turns and oil flows through the BrakeSaver compartment, it takes the shape of a triangle.

_____g. The oil flow is constantly cut by the vanes of the rotor; this cutting action gives resistance to the oil.

_____h. When BrakeSaver is in operation, the level of braking can be controlled by the inlet oil pressure, since the amount of oil is cut by the rotor vanes.

_____i. When BrakeSaver is not in operation, the inlet passage to the rotor is opened by the control valve and there is oil in the BrakeSaver compartment.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

6. Demonstrate the ability to:

   a. Adjust a Jacobs engine brake on a Detroit diesel. (Job Sheet #1)

   b. Troubleshoot a Caterpillar BrakeSaver. (Job Sheet #2)

   c. Remove a BrakeSaver on a Caterpillar diesel engine. (Job Sheet #3)

   d. Disassemble a BrakeSaver. (Job Sheet #4)

   e. Assemble a BrakeSaver. (Job Sheet #5)

   f. Install a BrakeSaver. (Job Sheet #6)

   g. Install a Jacobs engine brake on a Mack diesel. (Job Sheet #7)

   h. Adjust slave piston of a Jacobs engine brake on a Mack diesel. (Job Sheet #8)

ENGINE BRAKES AND RETARDERS
UNIT IV-C

ANSWERS TO TEST

1. a. 4
   b. 1
   c. 7
   d. 2
   e. 5
   f. 3
   g. 6

2. a, b, c, f, g

3. b. Missing or damaged
   d. Center solenoid valve seal
   e. Fail to close
   g. "On" position

4. a. Extended up to five times
   b. Lowering overall maintenance costs
   d. Tire life and wear
   e. Shorter round trip schedules

5. a, c, d, e, g, h

6. Performance skills evaluated to the satisfaction of the instructor

PREVENTIVE MAINTENANCE
UNIT I-D

UNIT OBJECTIVE

After completion of this unit, the student should be able to use a checklist to perform preventive maintenance. The student should also be able to recognize symptoms to prevent major repairs. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to preventive maintenance with the correct definitions.
2. Select true statements concerning facts about daily PM's.
3. Complete statements concerning weekly PM's.
4. List hourly, mileage, or "as required" PM's.
5. Demonstrate the ability to:
    a. Perform a daily PM service. (Job Sheet #1)
    b. Perform a weekly PM service. (Job Sheet #2)
    c. Perform a mileage, hourly, or "as required" PM service. (Job Sheet #3)

PREVENTIVE MAINTENANCE
UNIT I-D

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information sheet.

E. Discuss information sheet.

F. Provide students with job sheets.

G. Discuss and demonstrate the procedures outlined in the job sheets.

H. Integrate the following activities throughout the teaching of this unit:

1. Have students make a checklist for PM's.
2. Demonstrate some of the checks.
3. Have students locate air, fuel, and oil filters.
4. Have students locate fluid dipsticks.
5. Have students do walk-around checks.
6. Show students how to use and read a manometer.
7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

I. Give test.

J. Evaluate test.

K. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Basic Maintenance Guide.* Morton, IL: Caterpillar, Inc., 1985.

B. *DT 466 Shop Manual.* Westmont, IL: International Harvester, November, 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. Texts

1. *Detroit Engine Service Manual*
13400 Outer Drive West
Detroit, MI 48239-4001

B. Filmstrip

1. *PM Means Pocket Money* (20 slides and script)
Caterpillar, Inc., Literature
P.O. Box 5319
Morton, IL 61550

PREVENTIVE MAINTENANCE
UNIT I-D

INFORMATION SHEET

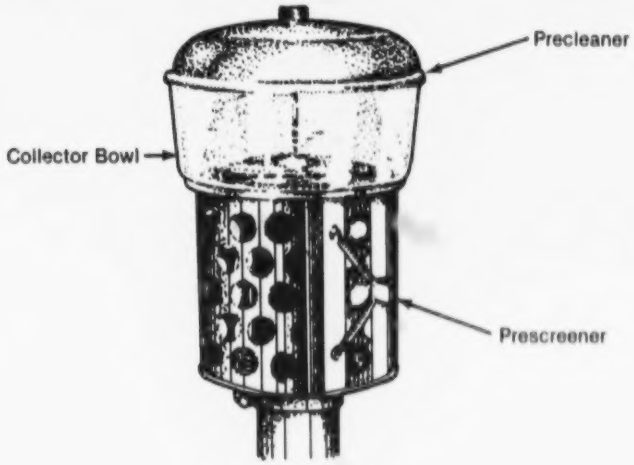
I. **Terms and definitions**

A. Checklist — Inspection points, in logical order, for determining if maintenance or service is needed

B. Log — Form for keeping operation and maintenance records

C. PM — Preventive maintenance (scheduled)

D. Precleaner — Device which removes large particles of dirt or other foreign matter from the air before it enters the main air cleaner



E. Symptom — Indication of mechanical trouble

II. **Daily PM — Check the following items every day**

A. Fluid and air system leaks

B. Fluid levels (oils, coolant and fuel)

C. Belt wear and belt tension

D. Gauge condition (broken or defective units)

E. Air precleaner condition (if used)

(NOTE: Precleaners are used on off-road equipment and in dusty conditions.)

INFORMATION SHEET

F. Water present in tank and/or fuel filter(s)

(NOTE: Some vehicles have water separators with clear glass bowl.)

III. Weekly PM — Check the following items weekly

A. Battery corrosion and electrolyte level

(NOTE: Fill battery with clean water.)

B. Hydraulic fluid level

(NOTE: Some vehicles have a dipstick; others use a sight glass in the reservoir.)

C. Manufacturer's specification for grease (off-road equipment)

IV. Mileage, hourly or "as required" PM's — Make checks according to the manufacturer's specifications or at discretion of mechanic

A. Tire wear, defects and air pressure

B. Air filters, black smoke

(NOTE: If red piston in air cleaner indicator is visible, the filter is restricted.)

C. Fuel level and cleanliness

(NOTE: Fuel should be stored in proper container)

D. Fuel filters

(NOTE: Fuel filters should be changed as required or at manufacturer's recommended intervals.)

E. Radiator fin trash and dirt

(NOTE: Dirt will be found in off-road equipment.)

F. Bellypan condition (off-road equipment)

G. Quantity of antifreeze using antifreeze tester

PREVENTIVE MAINTENANCE
UNIT I-D

JOB SHEET #1 — PERFORM DAILY PM SERVICE

A. Tools and materials

1. Vehicle
2. Shop towels
3. Coolant
4. Oils
5. Appropriate service manual
6. Daily checklist
7. Clean container
8. Clean funnel

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Walk around the vehicle and check for any fluid leaks.
2. Determine what type of fluid is leaking.

   (NOTE: Fluids are identified by color, feel and smell.)

3. Check radiator for coolant level.
   a. Fill to manufacturer's specifications.
   b. Check cleanliness of coolant.

      (CAUTION: Do not remove radiator cap on pressure systems when vehicle engine is hot. Serious burns could result.)

4. Check engine oil level.
   a. Remove dipstick and wipe dry.
   b. Replace dipstick in dipstick tube making sure it is seated properly.

JOB SHEET #1

   c. Remove dipstick and check oil level.

   d. Clean filler cap before removing if oil is needed.

5. Check fuel level.

   a. Check fuel gauge or remove filler cap to check fuel level.

      (NOTE: Some equipment will have a dipstick to check fuel level.)

   b. Drain some fuel from vehicles equipped with drain tank.

      1) Check for water in fuel.

      2) Check for trash in fuel.

6. Check gauges.

   a. Look for broken glass or moisture.

   b. Check for defective/inoperative gauges.

7. Check air precleaner.

   a. Look for dirt in precleaner.

   b. Remove and clean if necessary.

8. Drain fuel from fuel filter(s), and check for water and trash in filters and tank.

SAMPLE CHECKLIST:

DAILY PM'S

	YES	NO
1. Fluid leaks	______	______
2. Air system leaks	______	______
3. Correct fluid levels	______	______
4. Belts frayed or slack	______	______
5. Gauges broken or defective	______	______
6. Precleaner dirty	______	______

PREVENTIVE MAINTENANCE
UNIT I-D

JOB SHEET #2 — PERFORM WEEKLY PM SERVICE

A. Tools and materials

1. Vehicle
2. Shop towels
3. Clean or distilled water
4. Hydraulic oil
5. Appropriate service manual
6. Clean container
7. Clean funnel(s)
8. Grease gun
9. Check list

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Check batteries.
    a. Check batteries or corrosion at post and battery cable clamps.
        1) Use battery post cleaner or water/soda mixture to clean corrosion.
        2) Put grease on post when clean.

        (NOTE: Grease slows down corrosion.)
    b. Check electrolyte level in battery.
        1) Fill with clean or distilled water.
        2) Add water to bring level above the plates in each cell.

JOB SHEET #2

2. Check hydraulic fluid level.

   (NOTE: Some vehicles use the same procedure as checking engine oil.)

   a. Usually check the sight glass for fluid level.

   b. Clean filler cap before removing.

   c. Fill to correct level.

3. Grease equipment.

   a. Locate fitting on checklist.

   b. Wipe fitting clean.

   c. Grease until grease appears or according to manufacturer's specifications.

JOB SHEET #2

SAMPLE CHECKLIST:

WEEKLY PM'S

	YES	NO
1. Battery cables corroded.	______	______
2. Electrolyte level correct.	______	______
3. Hydraulic fluid at correct level.	______	______
4. Greased to manufacturer's specifications.	______	______

PREVENTIVE MAINTENANCE
UNIT I-D

JOB SHEET #3 — PERFORM MILEAGE, HOURLY, OR "AS REQUIRED" PM SERVICE

A. Tools and materials

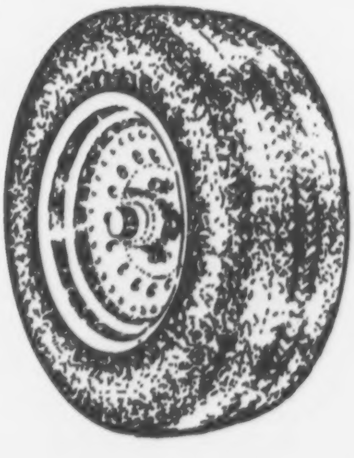
1. Vehicle
2. Shop towels
3. Tire pressure gauge
4. PM checklist
5. Appropriate service manual
6. Grease gun
7. Water manometer

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Check tires.
   a. Check tire pressure.
   b. Check tire wear. (Figure 1)

FIGURE 1



   c. Check for breaks or defects.

JOB SHEET #3

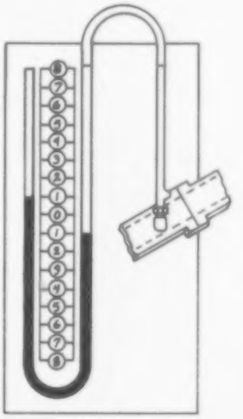
2. Check air filter(s).

   a. Check for excessive black smoke.

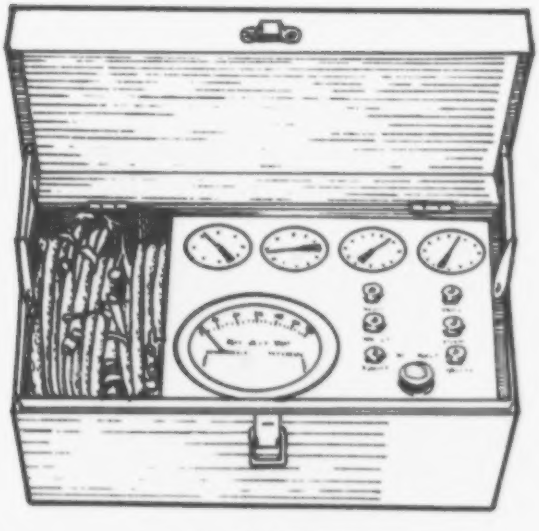
   b. Check air filter indicator. If red indicator is visible, air filter is restricted.

   c. Check air filters without indicator with water manometer or magnahelic gauge. (Figure 2)

FIGURE 2



Water Manometer

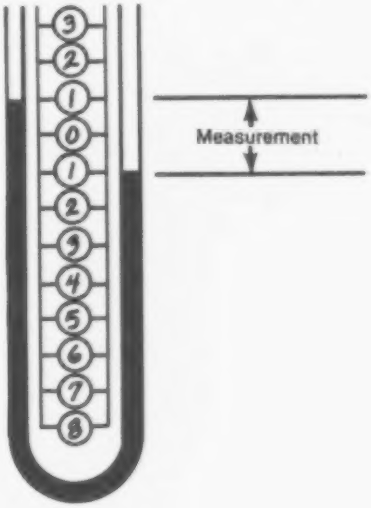


Magnahelic Gauge

JOB SHEET #3

d. Read water manometer in inches of water figuring the difference of the two columns of water. (Figure 3)

FIGURE 3



3. Check fuel.

   a. Drain some fuel in to a clean container.

   b. Check for trash.

   c. Check color and odor.

4. Clean radiator of trash and dirt.

   a. Remove trash.

   b. Blow out fins with air hose.

   c. Wash radiator with high pressure hose to remove dirt and oil.

5. Clean bellypan.

6. Check coolant with antifreeze tester.

7. Clean the bellypan on off-road equipment.

   a. Support bellypan with jack.

   b. Remove bolts in bellypan.

   c. Lower bellypan.

   d. Clean bellypan.

JOB SHEET #3

SAMPLE CHECKLIST:

MILEAGE, HOURLY, OR "AS REQUIRED" PM'S

	YES	NO
1. Tires excessively worn or defective	______	______
2. Tires at proper inflation pressure	______	______
3. Excessive smoke in air filter	______	______
4. Fuel level appropriate for activity	______	______
5. Fuel tank clean	______	______
6. Extra fuel in proper container	______	______
7. Fuel filter clean/changed	______	______
8. Radiator fins free of trash and dirt	______	______
9. Bellypans clean	______	______
10. Coolant tested for antifreeze content	______	______

PREVENTIVE MAINTENANCE
UNIT I-D

PRACTICAL TEST
JOB SHEET #1 — PERFORM DAILY PM SERVICE

STUDENT'S NAME ______________________________ DATE ______________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked for leaks.	______	______
3. Determined type of fluid.	______	______
4. Checked coolant level.	______	______
5. Filled to proper level.	______	______
6. Checked and filled oil levels.	______	______
7. Checked and filled fuel level.	______	______
8. Checked gauges.	______	______
9. Checked precleaner.	______	______
10. Checked for water in fuel.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Performed correctly daily PM checks				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PREVENTIVE MAINTENANCE
UNIT I-D

PRACTICAL TEST
JOB SHEET #2 — PERFORM WEEKLY PM SERVICE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked batteries.	______	______
3. Cleaned batteries.	______	______
4. Filled batteries.	______	______
5. Checked hydraulic fluid.	______	______
6. Greased equipment.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Performed weekly PM service correctly				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PREVENTIVE MAINTENANCE
UNIT I-D

PRACTICAL TEST
JOB SHEET #3 — PERFORM MILEAGE, HOURLY, OR "AS REQUIRED" PM SERVICE

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Checked tires.	______	______
3. Checked filters.	______	______
4. Checked fuel.	______	______
5. Checked radiator fins for trash and dirt.	______	______
6. Cleaned bellypan.	______	______
7. Checked antifreeze.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Performed PM service checks correctly				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

PREVENTIVE MAINTENANCE
UNIT I-D

NAME ____________________ SCORE ____________________

TEST

1. Match terms related to preventive maintenance with the correct definitions.

_____a. Indication of mechanical trouble

_____b. Preventive maintenance

_____c. Form for keeping operation and maintenance records

_____d. Inspection points, in logical order, for determining if maintenance or service is needed

_____e. Device which removes large particles of dirt or other foreign matter from the air before it enters the main air cleaner

1. Precleaner
2. Log
3. PM
4. Symptom
5. Checklist

2. Select true statements concerning facts about daily PM's by placing an "X" beside each statement that is true.

_____a. Check for leaks in the fluid and air systems.

_____b. Check levels of the fluids.

_____c. Check belts for grease and tension.

_____d. Check gauges for broken or defective units.

_____e. Check air precleaner for oil.

_____f. Drain some of the oil from tank and fuel filters.

3. Complete statements concerning weekly PM service by inserting the correct word(s) in each blank.

a. Check batteries for corrosion and ____________ level.

b. Check hydraulic ____________ level.

c. Grease ____________ equipment weekly.

TEST

4. List any four hourly, mileage, or "as required" PM's.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

5. Demonstrate the ability to:

   a. Perform a daily PM service. (Job Sheet #1)

   b. Perform a weekly PM service. (Job Sheet #2)

   c. Perform a mileage, hourly, or "as required" PM. (Job Sheet #3)

PREVENTIVE MAINTENANCE
UNIT I-D

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 2
   d. 5
   e. 1

2. a, b, d

3. a. Electrolyte or acid
   b. Fluid or oil
   c. Off-road

4. Any four of the following:

   a. Check tires for wear, defects, and air pressure.
   b. Check air filters.
   c. Check fuel level and cleanliness of fuel.
   d. Check fuel filters.
   e. Clean radiator fins of trash and dirt as required.
   f. Clean bellypans of off-road equipment.
   g. Check coolant for quantity of antifreeze.

5. Performance skills evaluated to satisfaction of instructor

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

UNIT OBJECTIVE

After completion of this unit, the student should be able to load test an engine with a dynamometer and test engine cylinder compression. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to troubleshooting and testing of engines with the correct definitions.
2. Arrange in order the steps in troubleshooting and testing an engine.
3. List major checkpoints when inspecting a diesel engine.
4. Complete a list of major checks to make when operating an engine.
5. List tests that are made with a dynamometer.
6. Name factors necessary for an engine to produce horsepower.
7. Select possible causes of a diesel engine being hard to start or not starting.
8. Select possible causes of a diesel engine starting but not running.
9. Complete a list of items which would cause a diesel engine to misfire.
10. Select the items which would cause a diesel engine to knock.

OBJECTIVE SHEET

11. Select items which would cause a diesel engine to overheat.
12. Circle items which would cause a diesel engine to have lack of power.
13. Select items which would cause a diesel engine to use too much oil.
14. Name causes of high oil pressure.
15. List causes of low oil pressure.
16. Complete a diesel troubleshooting guide. (Assignment Sheet #1)
17. Demonstrate the ability to:
    a. Load test an engine with a dynamometer. (Job Sheet #1)
    b. Test engine cylinder compression. (Job Sheet #2)
    c. Check air intake system for restrictions. (Job Sheet #3)
    d. Check crankcase pressure, exhaust back pressure, and air box pressure. (Job Sheet #4)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information and assignment sheets.

E. Discuss information and assignment sheets.

F. Provide students with job sheets.

G. Discuss and demonstrate the procedures outlined in the job sheets.

H. Integrate the following activities throughout the teaching of this unit:

1. Explain how to properly use and read a mercury and a water-filled manometer.
2. Show students film on dust conditions.
3. Have students make a list of torque loss items.
4. Have students draw a compression gauge.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

I. Give test.

J. Evaluate test.

K. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins Engine Company Shop Manual.* Columbus, IN: Cummins Engine Company, 1974.

B. Dagel, John F. *Diesel Engine Repair.* New York: John Wiley and Sons, Inc., 1982.

C. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

REFERENCES USED IN DEVELOPING THIS UNIT

D. Kates, Edgar J. and William E. Luck. *Diesel and High Compression Gas Engines*. Chicago: American Technical Society, 1974.

E. *Service Manual, Detroit Diesel Engines*. Detroit, MI: Detroit Diesel Allison, 1985.

F. Toboldt, Bill. *Diesel: Fundamentals. Service, Repair.* South Holland, IL: Goodheart-Willcox Company, 1980.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

1. Schulz, Erich J. *Diesel Mechanics*. 2nd ed. New York: McGraw-Hill, 1983.

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

INFORMATION SHEET

I. **Terms and definitions**

A. Dynamometer — Instrument for measuring the power output of an engine by applying a load to the engine, thereby testing the horsepower and torque

B. Manometer — Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns

(NOTE: Magnahelic gauge is sometimes used in place of water manometer.)

C. Pyrometer — Instrument for measuring temperatures beyond the range of a mercurial thermometer

D. Tachometer — Device measuring speed of rotation

E. Troubleshoot — In engine service, the use of instruments to diagnose the engine parts to locate the cause of failure

II. **Steps in troubleshooting and testing an engine**

A. Ask the operator.

(NOTE: Ask operator what warning signs preceeded the trouble; what previous work has been done on the engine; and if similar trouble has occurred before.)

B. Know the system.

(NOTE: Study technical manuals, how engine works, knowledge of three basic needs: fuel-air mixture, compression, and ignition.)

C. Inspect the machine.

(NOTE: Check all fluid levels.)

D. Operate the machine.

E. List the possible causes.

F. Reach a conclusion.

G. Test your conclusion.

INFORMATION SHEET

III. **Major checkpoints**

- A. Cooling system
- B. Lubrication system
- C. Fuel system
- D. Electrical system
- E. Air intake system
- F. Exhaust system

(NOTE: Keep a list of all trouble signs noted from above checks.)

IV. **Checks when operating an engine**

- A. Gauge readings
- B. Unusual sounds (where? at what speed?)
- C. Smells (any signs of unusual exhaust)
- D. Smoke (black, blue, white)
- E. Controls
- F. Power under load
- G. Idle speed (low-high)
- H. Alternator or charging system

V. **Tests made with a dynamometer**

- A. Engine horsepower or torque
- B. Exhaust smoke analysis
- C. Fuel consumption
- D. Crankcase blow-by
- E. Air cleaner restriction
- F. Oil pressure
- G. Clutch operation
- H. Manifold boost pressure

INFORMATION SHEET

  I. Exhaust temperature

  J. Air box pressure

  K. Exhaust back pressure

VI. Factors necessary to produce horsepower

  A. Fuel-air mixture

  B. Compression

  C. Ignition

VII. Causes of a diesel engine being hard to start or not starting

  A. No fuel or improper fuel

  B. Water or dirt in fuel or dirty filters

  C. Air in fuel system

  D. Low cranking speed

  E. Faulty nozzle operation

  F. Improper timing

  G. Faulty injection pump

  H. Low compression

  I. Glow plugs

VIII. Causes of diesel engine starting but not running

  A. Dirt in fuel

  B. Suction leak

  C. Air restrictions

  D. Clogged filter

  E. Restriction in exhaust

  F. Safety switch

INFORMATION SHEET

IX. **Causes of diesel engine misfiring**

- A. Water or dirt in fuel
- B. Gasoline in diesel fuel
- C. Air in fuel system
- D. Faulty nozzle operation
- E. Faulty injection pump
- F. Nozzles not seated properly in cylinder head
- G. Low compression
- H. Glow plug (when engine is cold)

X. **Causes of diesel engine knock**

- A. Improper injection pump timing
- B. Worn engine bearings or bushings
- C. Excessive crankshaft end play
- D. Foreign material in cylinder
- E. Scored piston
- F. Faulty injection nozzle
- G. Bad fuel

XI. **Causes of diesel engine overheating**

- A. Defective radiator cap
- B. Radiator fins bent or plugged
- C. Defective thermostat
- D. Insufficient coolant
- E. Loose fan belt
- F. Cooling system limed up
- G. Overloaded engine
- H. Faulty engine timing

INFORMATION SHEET

I. Engine low on oil

J. Wrong type of fuel

K. Faulty water pump

L. Faulty shutter operation (if used)

M. Faulty nozzles

N. Fan problems

O. Head gasket

P. Cracked head

Q. Defective injection pump

XII. **Causes of a diesel engine having lack of power**

A. Air cleaner dirty or otherwise obstructed

B. Restricted air flow in intake system

C. Restriction in fuel lines or filters

D. Wrong type of fuel

E. Valve failure

F. Incorrect valve tappet clearance

G. Low engine speed (high idle)

H. Crankcase oil too heavy

I. Low compression

J. Low operating temperature

K. Faulty injection pump delivery

L. Exhaust restriction

M. Incorrect camshaft timing

INFORMATION SHEET

XIII. **Causes of a diesel engine using too much oil**

A. Crankcase oil too light

B. Worn pistons and rings

C. Worn valve guides or stem oil seals

D. Loose connecting rod bearings

E. External oil leaks

F. Oil pressure too high

G. Engine speed too high

H. Crankcase ventilator pump not working

I. Restricted air intake or breather

J. Excessive oil in rocker arm assembly

K. Wrong dipstick

L. Air compressor

M. Blower or turbocharger seals

XIV. **Causes of high oil pressure**

A. Stuck relief valve, wrong or switched (Detroit)

B. Defective pressure gauge

C. Wrong oil pump or pressure regulator

D. Oil too thick

XV. **Causes of low oil pressure**

A. Worn bearings

B. Poor relief valve seating

C. Too light oil

D. Worn oil pump

E. Engine low on oil

INFORMATION SHEET

F. Loose connection or leaky seals at oil filter, pump, or cooler

G. Defective oil pressure gauge

H. Dilution of oil

I. High level

J. Plugged oil filter (full flow)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

ASSIGNMENT SHEET #1 — COMPLETE A DIESEL TROUBLESHOOTING GUIDE

The following questions provide a guide for beginning analysis of troubleshooting a diesel.

Select the method on the right that would most likely answer the question.

_____ 1) Is acceleration normal?
_____ 2) How does it start when cold?
_____ 3) How does it start when hot?
_____ 4) Is there any misfiring?
_____ 5) Under what condition does it misfire?
_____ 6) Is exhaust normal?
_____ 7) Does the engine surge at any speed?
_____ 8) Is there any oil leakage?
_____ 9) Is there any coolant leakage?
_____10) Is there any fuel leakage?
_____11) Is there any air leakage from turbocharger or blower?
_____12) Does the engine run hot?
_____13) When was the last service work performed?
_____14) What work was done on the engine?
_____15) Under what conditions is the engine operated?
_____16) Are any knocks apparent?
_____17) Under what conditions are the knocks apparent?
_____18) What is operating temperature of individual cylinder exhaust?

a. Ask operator
b. Compression gauge
c. Dynamometer test
d. Operate engine
e. Pyrometer (if used)
f. Visual inspection

ASSIGNMENT SHEET #1

______19) Is exhaust gas analysis normal?

______20) Is there any restriction in air duct? Any leakage?

______21) What is the compression pressure of various cylinders?

______22) Has the brand of fuel been changed recently?

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. a
2. a
3. a
4. a, d
5. a
6. d
7. a, d
8. f
9. f
10. f
11. f
12. d
13. a
14. a
15. a
16. a, d
17. a, d
18. e
19. c
20. f, c
21. b
22. a

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

JOB SHEET #1 — LOAD TEST AN ENGINE WITH A DYNAMOMETER

A. Tools and materials

1. Basic hand tool set
2. Live engine
3. Dynamometer
4. Engine technical manual
5. Dynamometer instruction manual
6. Safety glasses

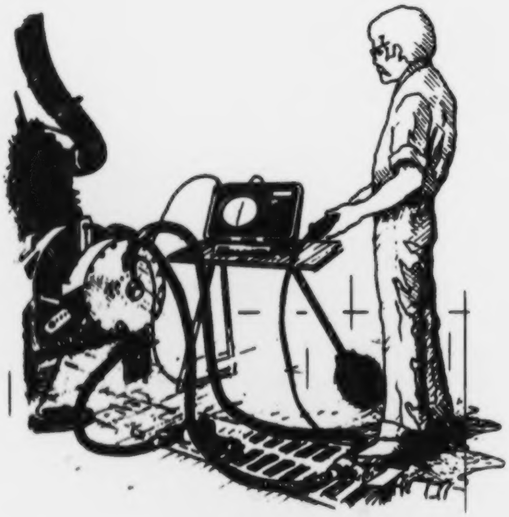
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Connect the engine to the dynamometer using the manufacturer's instructions. (Figure 1)

   (CAUTION: Rotating parts are a safety hazard.)

FIGURE 1



Portable Dynamometer

JOB SHEET #1

2. Operate the engine at about one-half load until the coolant and crankcase oil temperatures are up to normal.

   (NOTE: Warm up will take about 30 minutes but is very important to a good test. Keep close check on engine oil pressure and temperature during test.)

   (CAUTION: Break in new engine.)

3. Gradually increase the load on the engine until its speed is reduced to rated load speed as given in the engine technical manual.

4. Read the horsepower on the dynamometer.

   (NOTE: On some models a conversion chart or calculator is required to find horsepower. Horsepower can be affected by testing conditions such as altitude, humidity, and temperature.)

5. Compare the horsepower with that given in the engine technical manual.

   (NOTE: Do not expect engines to always equal these specifications. If the engine rates much lower than normal it is a signal that service is needed.)

6. While the engine is operating under load, note the outlet of the crankcase ventilating system.

7. Remove the crankcase oil filter cap if too much vapor appears.

   (NOTE: If an excessive amount of vapor or smoke appears here as well as at the vent, there is blow-by in the engine cylinders and they must be reconditioned before the engine will perform at its best.)

8. Check engine technical manual for specified amount of engine vapor flow.

   (NOTE: Any increase in flow over the specified amount indicates crankcase blow-by.)

9. Recondition the engine for good operation if the blow-by is excessive.

   (NOTE: Even though the engine develops its rated horsepower using a normal amount of fuel, a tune-up may still improve its efficiency. Consider both hours of operation and the conditions under which the engine has been operated. It is far more economical in the long run to tune the engine before a lack of performance makes it mandatory.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

JOB SHEET #2 — TEST ENGINE CYLINDER COMPRESSION

A. Tools and materials

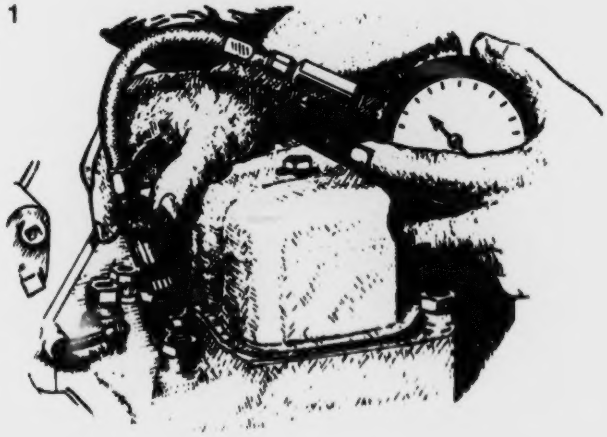
1. Basic hand tool set
2. Compression gauge
3. Live engine
4. Safety glasses
5. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Warm up the engine to operating temperature.
2. Remove the injectors, or injection nozzles.
3. Connect a pressure gauge to the cylinder port. (Figure 1)

FIGURE 1



4. Set the engine speed control to stop position.

JOB SHEET #2

5. Turn the engine with the starter until the pressure gauge registers no further rise in pressure.

   (NOTE: It is a good practice to count the number of compression strokes, indicated by movement of the gauge needle, and check each cylinder with the same number of strokes. The engine must be at full cranking speed or as specified in appropriate service manual to get a good reading.)

6. Check the pressure reading against the engine technical manual.

   (NOTE: Low pressure indicates leakage through valves, rings, or gaskets. Variations in cylinder pressures of more than 10% usually indicate a need for cylinder reconditioning.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

JOB SHEET #3 — CHECK AIR INTAKE SYSTEM FOR RESTRICTIONS

A. Tools and materials

1. Basic hand tool set
2. Live engine
3. Water filled manometer
4. Pipe tee
5. Shop towels
6. Safety glasses
7. Appropriate service manual

B. Procedure

(CAUTION: Follow all shop safety procedures.)

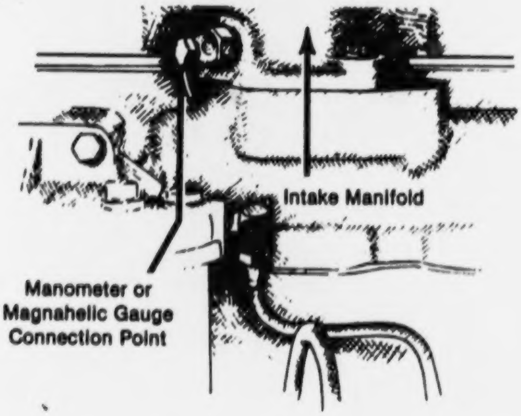
1. Check air intake system for restriction on a naturally aspirated engine.

   a. Connect manometer to manifold that does not have a restriction indicator.

      1) Connect manometer to side of intake manifold near middle of manifold or magnahelic gauge. (Figure 1)

         (NOTE: If a plug is not provided in the manifold intake area, make reading as close to engine as possible in intake piping.)

FIGURE 1



JOB SHEET #3

    2) Start engine and bring to normal operating temperature and governed speed.

    3) Check the normal air inlet vacuum at various speeds (no load).

    4) Compare results with the engine technical manual operating specifications.

  b. Connect manometer to manifold with restriction indicator.

    1) Remove the indicator.

    2) Install a pipe tee fitting.

    3) Reinstall the indicator.

    4) Connect the gauge to the tee fitting.

    5) Start engine and bring to normal operating temperature and governed speed.

    6) Check the normal air inlet vacuum at various speeds (no load).

    7) Compare results with the engine technical manual operating specifications.

  c. Check the operation of the air restriction indicator, if used.

    1) Use a board or metal plate to slowly cover the air intake opening.

    2) Note the action of the indicator in relation to the reading on the gauge.

    3) Replace indicator if it does not operate properly.

2. Check air intake system for restriction on a turbocharged engine.

  a. Connect manometer to air intake pipe.

  (NOTE: Connection should be made about 2" upstream from turbocharger inlet, in a straight section of pipe.)

  b. Start engine and bring to normal operating temperature and at governed speed.

  c. Measure the restriction when engine is under full load.

  (NOTE: On some engines you may remove the air cleaner and ducting and note the gauge readings at various speeds; the difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaning and ducting.)

  d. Compare results with the engine technical manual operating specifications.

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

JOB SHEET #4 — CHECK CRANKCASE PRESSURE, EXHAUST BACK PRESSURE, AND AIR BOX PRESSURE

A. Tools and materials

1. Basic hand tool set
2. Live engine
3. Water filled manometer
4. Mercury filled manometer
5. 1/8" pipe plug
6. Small tap and die set
7. Shop towels
8. Safety glasses
9. Appropriate service manual

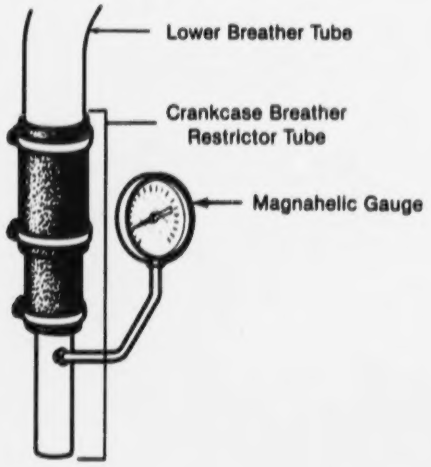
B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Check crankcase pressure.

   a. Connect water manometer to the crankcase breather tube. (Figure 1)

FIGURE 1


Lower Breather Tube
Crankcase Breather Restrictor Tube
Magnahelic Gauge

JOB SHEET #4

b. Operate the engine at manufacturer's rated load speeds and note the readings obtained.

c. Compare the readings to specifications in the engine technical manual operating conditions.

2. Check exhaust back pressure.

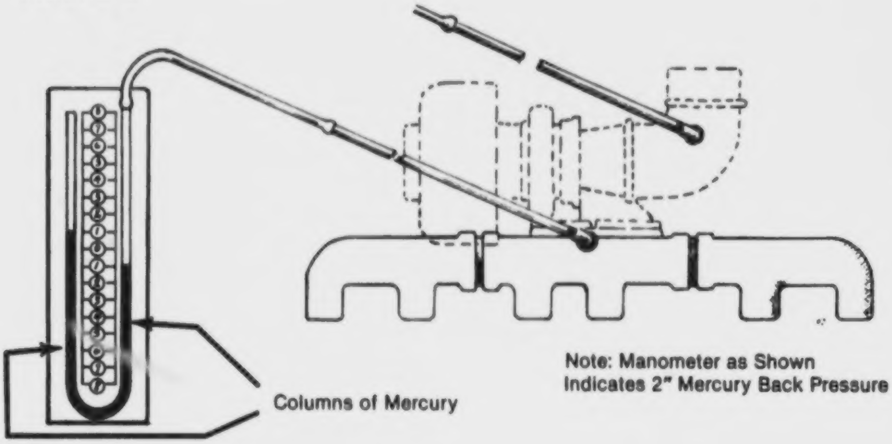
   a. Remove 1/8" pipe plug in exhaust manifold.

   (NOTE: If no opening is provided, drill an 11/32" hole in exhaust manifold companion flange and tap the hole to accomodate a 1/8" pipe plug.)

   b. Connect the mercury manometer to the exhaust manifold. (Figure 2)

   (NOTE: On turbocharged engines check the exhaust back pressure in the exhaust piping 6" to 12" from the turbine outlet.)

FIGURE 2



Note: Manometer as Shown Indicates 2" Mercury Back Pressure

   c. Start engine and operate to normal operating conditions.

   d. Take back pressure readings when engine is developing rated horsepower at governed speed.

JOB SHEET #4

e. Add reading of mercury in both columns for final figure. (Figure 2)

Example: If mercury is 1 inch high in left column and 1 inch low in right column, there is 2 inches of pressure; if mercury is 1 inch high in right column and 1 inch low in left column, there is 2 inches of vacuum.

f. Check the engine technical manual operating conditions for maximum permissible back pressure.

3. Check air box pressure.

a. Connect manometer to an air box drain tube.

b. Operate the engine at manufacturer's rated load speed and note pressure readings.

c. Compare readings with the engine technical manual operating conditions.

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

PRACTICAL TEST
JOB SHEET #1 — LOAD TEST AN ENGINE WITH A DYNAMOMETER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Connected engine to dynamometer.	______	______
3. Warmed up engine. (Broke in new engine.)	______	______
4. Checked horsepower with dynamometer.	______	______
5. Checked blow by.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Performed load test correctly				

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

PRACTICAL TEST
JOB SHEET #2 — TEST ENGINE CYLINDER COMPRESSION

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Warmed up engine.	______	______
3. Removed injectors or nozzles.	______	______
4. Connected compression gauge.	______	______
5. Stopped engine.	______	______
6. Checked compression and recorded.	______	______
7. Compared pressure reading against specifications.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Checked compression correctly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

PRACTICAL TEST
JOB SHEET #3 — CHECK AIR INTAKE SYSTEM FOR RESTRICTIONS

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. _____

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.		
2. Connected manometer to intake.		
3. Started engine.		
4. Connected manometer.		
5. Checked operation of the air restriction indicator.		
6. Checked air intake system for restriction.		
7. Measured the restriction when engine was under full load.		
8. Compared results.		
9. Checked in/put away tools and materials.		
10. Cleaned the work area.		
11. Used proper tools correctly.		
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)		
13. Practiced safety rules throughout procedure.		
14. Provided satisfactory responses to questions asked.		

EVALUATOR'S COMMENTS: ______________________________________

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
	4	3	2	1
Determined condition of air filter				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

PRACTICAL TEST
JOB SHEET #4 — CHECK CRANKCASE PRESSURE, EXHAUST BACK PRESSURE, AND AIR BOX PRESSURE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Connected manometer or magnahelic gauge.	______	______
3. Operated the engine and noted reading.	______	______
4. Compared reading with specifications.	______	______
5. Repeated above steps for exhaust and air box pressure.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Pressure of crankcase, exhaust and air box pressure properly checked				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

NAME ____________________ SCORE ____________________

TEST

1. Match the terms related to troubleshooting and testing engines with the correct definitions.

_____a. In engine service, the use of instruments to diagnose the engine parts to locate the cause of failure

_____b. Instrument for measuring the power output of an engine applying a load to the engine, thereby testing the horsepower and torque

_____c. Instrument using mercury or water in a U-tube, indicating positive or negative (vacuum) pressure by the difference in height of the two columns

_____d. Device measuring speed of rotation

_____e. Instrument for measuring temperatures beyond the range of a mercurial thermometer

1. Dynamometer
2. Manometer
3. Pyrometer
4. Tachometer
5. Troubleshoot

2. Arrange in order the steps in troubleshooting and testing an engine by placing the correct sequence number beside each step.

_____a. Operate the machine.

_____b. Reach a conclusion.

_____c. Ask the operator.

_____d. Inspect the machine.

_____e. List the possible causes.

_____f. Know the system.

_____g. Test your conclusion.

TEST

3. List four of the six major checkpoints when inspecting a diesel engine.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

4. Complete the following list of major checks to make when operating an engine.

   a. Gauge readings

   b. ______________________________

   c. Smells

   d. ______________________________

   e. Controls

   f. Power under load

   g. Idle speed

   h. Alternator or charging system

5. List six tests that are made with a dynamometer.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

6. Name three factors necessary for an engine to produce horsepower.

   a. ______________________________

   b. ______________________________

   c. ______________________________

TEST

7. Select the possible causes of a diesel engine being hard to start or not starting by placing an "X" beside the cause(s).

_____a. Low cranking speed

_____b. Faulty nozzle operation

_____c. Cracked or eroded distribution rotor bug

_____d. Defective coil or condenser

_____e. Air in fuel system

_____f. Improper timing

_____g. Water or dirt in fuel or dirty filters

_____h. Too heavy oil in air cleaner

_____i. No fuel or improper fuel

_____j. Faulty injection pump

8. Select the possible causes of a diesel engine starting but not running by placing an "X" beside the cause(s).

_____a. Dirt in fuel

_____b. Air restrictions

_____c. Clogged filter

_____d. Defective coil or condenser

9. Complete the following list of items which would cause a diesel engine to misfire.

a. Water or dirt in fuel

b. Gasoline in diesel fuel

c. Air in fuel system

d. Faulty nozzle operation

e. ____

f. Nozzles not seated properly in cylinder head

g. ____

TEST

10. Select the items which would cause a diesel engine to knock by placing an "X" beside the cause(s).

_____a. Improper injection pump timing

_____b. Worn engine bearings or bushings

_____c. Excessive crankshaft end play

_____d. Foreign material in cylinder

_____e. Restricted fuel line

11. Select the items which would cause a diesel engine to overheat by placing an "X" beside the cause(s).

_____a. Defective radiator cap

_____b. Radiator fins bent or plugged

_____c. Defective thermostat

_____d. Insufficient coolant

_____e. Loose fan belt

_____f. Cooling system limed up

_____g. Overloaded engine

_____h. Faulty engine timing

_____i. Distributor advance mechanism stuck

_____j. Engine low on oil

_____k. Wrong type of fuel

_____l. Faulty shutter operation (if used)

12. Circle the items which would cause a diesel engine to have lack of power.

a. Air cleaner dirty or otherwise obstructed

b. Restricted air flow in intake system

c. Restriction in fuel lines or filters

d. Wrong type of fuel

TEST

e. Frost at fuel-lock strainer

f. Governor grinds

g. Distributor points burned

h. Incorrect camshaft timing

i. Low operating temperature

j. Faulty injection pump delivery

k. Improper hitching or belting of machine

l. Valve failure

m. Incorrect valve tappet clearance

n. Low engine speed (high idle)

o. Crankcase oil too heavy

p. Low compression

13. Select the items which would cause a diesel engine to use too much oil by placing an "X" beside the cause(s).

_____a. Crankcase oil too light

_____b. Worn pistons and rings

_____c. Worn valve guides or stem oil seals

_____d. Loose connecting rod bearings

_____e. External oil leaks

_____f. Oil pressure too high

_____g. Engine speed too high

_____h. Crankcase ventilator pump not working

_____i. Restricted air intake or breather

_____j. Excessive oil in rocker arm assembly

_____k. Oil pressure too low

TEST

14. Name two causes of high oil pressure.

    a. ____________________

    b. ____________________

15. List five causes of low oil pressure.

    a. ____________________

    b. ____________________

    c. ____________________

    d. ____________________

    e. ____________________

(NOTE: IF the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

16. Complete a diesel troubleshooting guide. (Assignment Sheet #1)

17. Demonstrate the ability to:

    a. Load test an engine with a dynamometer. (Job Sheet #1)

    b. Test engine cylinder compression. (Job Sheet #2)

    c. Check air intake system for restrictions. (Job Sheet #3)

    d. Check crankcase pressure, exhaust back pressure, and air box pressure. (Job Sheet #4)

TROUBLESHOOTING AND TESTING OF ENGINES
UNIT II-D

ANSWERS TO TEST

1. a. 5
   b. 1
   c. 2
   d. 4
   e. 3

2. a. 4
   b. 6
   c. 1
   d. 3
   e. 5
   f. 2
   g. 7

3. Any four of the following:

   a. Cooling system
   b. Lubrication system
   c. Fuel system
   d. Electrical system
   e. Air intake system
   f. Exhaust system

4. b. Unusual sounds
   d. Smoke

5. Any six of the following:

   a. Engine horsepower
   b. Exhaust smoke analysis
   c. Fuel consumption
   d. Crankcase blow-by
   e. Air cleaner restriction
   f. Oil pressure
   g. Clutch operation
   h. Manifold boost pressure
   i. Exhaust temperature
   j. Air box pressure
   k. Exhaust back pressure

6. a. Fuel-air mixture
   b. Compression
   c. Ignition

ANSWERS TO TEST

7. a, b, e, f, g, i, j

8. a, b, c

9. e. Faulty injection pump
   g. Low compression

10. a, b, c, d

11. a, b, c, d, e, f, g, h, j, k, l

12. a, b, c, d, h, i, j, l, m, n, o, p

13. a, b, c, d, e, f, g, h, i, j

14. Any two of the following:

    a. Stuck relief valve
    b. Defective pressure gauge
    c. Wrong oil pump or pressure regulator
    d. Oil too thick

15. Any five of the following:

    a. Worn bearings
    b. Poor relief valve seating
    c. Too light oil
    d. Worn oil pump
    e. Engine low on oil
    f. Loose connection or leaky seals at oil filter, pump, or cooler
    g. Defective oil pressure gauge
    h. Dilution of oil
    i. High level
    j. Plugged oil filter

16. Evaluated to the satisfaction of the instructor

17. Performance skills evaluated to the satisfaction of the instructor

TUNE-UP AND ADJUSTMENT
UNIT III-D

UNIT OBJECTIVE

After completion of this unit, the student should be able to tune-up and service various diesel engines. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Define terms related to tune-up and adjustment.
2. Complete a list of major items to include in a visual inspection checklist.
3. Demonstrate the ability to:
    a. Tune-up and service a diesel engine. (Job Sheet #1)
    b. Tune-up a Cummins diesel engine (Torque Method). (Job Sheet #2)
    c. Tune-up a Cummins diesel engine (Dial Indicator Method). (Job Sheet #3)
    d. Tune-up a Detroit diesel engine. (Job Sheet #4)
    e. Tune-up a 3400 series Caterpillar diesel engine. (Job Sheet #5)

TUNE-UP AND ADJUSTMENT
UNIT III-D

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

  1. Discuss procedures for stopping a "run-away" engine.
  2. Discuss three valve adjustment methods.
  3. Demonstrate valve wear problems.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Cummins L10 Shop Manual.* Louisville, KY: Cummins Engines, Inc., 1985.

B. *Fundamentals of Service: Engines.* 5th ed. Moline, IL: Deere and Company, 1980.

C. *Service Manual Detroit Diesel Engines.* Detroit, MI: Detroit Allison, 1985.

D. *Service Manual: 3406 Engine.* Peoria, IL: Caterpillar Tractor Co., 1985.

SUGGESTED SUPPLEMENTAL RESOURCES

A. **Texts**

1. *Diesel Engine Repair* (by John F. Dagel)
   John Wiley and Sons, Inc.
   New York, NY 10019

2. *Diesel Mechanics* (by Erich Schulz)
   McGraw-Hill Book Company
   Dallas, TX 75202

TUNE-UP AND ADJUSTMENT
UNIT III-D

INFORMATION SHEET

I. **Terms and definitions**

A. Replace — To install a new or rebuilt component or part

B. Service — To clean, inspect, adjust, lubricate, or repair a component or part as needed

C. Tune-up — Process of making checks and minor adjustments to improve the operation of the engine

(NOTE: Some companies consider tune-up to be preventive maintenance.)

II. **Visual inspection checklist**

(NOTE: Engine should be kept as clean as possible.)

A. Oil and water leakage

B. Electrical system

C. Cooling system

D. Air intake system

E. Fuel system

TUNE-UP AND ADJUSTMENT
UNIT III-D

JOB SHEET #1 — TUNE-UP AND SERVICE A DIESEL ENGINE

A. Tools and materials

1. Basic hand tool set
2. Compression tester with adapters
3. Appropriate engine special tools
4. Torque wrench
5. Nozzle tester
6. Radiator and radiator cap tester
7. Thermostat tester
8. Dynamometer
9. Appropriate engine service manuals
10. Dynamometer technical manual
11. Battery service manual
12. Safety glasses

B. Procedure

(NOTE: In the spaces to the right of each step, indicate the action which was taken. Inspection is the preliminary step prior to either servicing or replacing the component. Serviced means that the component or component part has been cleaned, inspected, adjusted, lubricated or repaired as needed. Replaced means that new or rebuilt components or component parts have been installed.)

	Inspected	Serviced	Replaced
1. Service air intake and exhaust system.			
a. Clean precleaner (if used).	☐	☐	☐
b. Remove and clean air cleaner.	☐	☐	☐
c. Swab out inlet pipe in air cleaner body.	☐	☐	☐

JOB SHEET #1

	Inspected	Serviced	Replaced
d. Inspect exhaust system and muffler.	☐	☐	☐
e. Check crankcase ventilating system for restrictions.	☐	☐	☐
2. Service basic engine			
a. Recheck air intake for restrictions.	☐	☐	☐
b. Check radiator for air bubbles or oil indicating compression or oil leaks.	☐	☐	☐
c. Check for leakage at cylinder head gasket.	☐	☐	☐
d. Retighten cylinder head cap screws.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
e. Adjust valve clearance.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
f. Check compression pressure in each cylinder.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
3. Service fuel system.			
a. Check fuel lines for leaks or restrictions.	☐	☐	☐
b. Clean fuel pump sediment bowl.	☐	☐	☐
c. Test fuel pump pressure.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			

JOB SHEET #1

	Inspected	Serviced	Replaced
d. Check speed control linkage.	☐	☐	☐
e. Service diesel fuel filters.	☐	☐	☐
f. Check diesel injection pump.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
g. Check and clean diesel injection nozzles.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
h. Bleed diesel fuel system.	☐	☐	☐
i. Check diesel injection pump timing.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
4. Service lubrication system.			
a. Check operation of pressure gauge or light.	☐	☐	☐
b. Service oil filter.	☐	☐	☐
c. Check condition of crankcase oil.	☐	☐	☐
d. Check engine oil pressure.	☐	☐	☐
5. Service cooling system.			
a. Check water pump for leaks and excessive shaft end play.	☐	☐	☐
b. Inspect radiator hoses.	☐	☐	☐
c. Clean and flush cooling system.	☐	☐	☐

JOB SHEET #1

	Inspected	Serviced	Replaced
d. Test thermostat and pressure cap.	☐	☐	☐
e. Test radiator for leaks.	☐	☐	☐
f. Check condition of fan belt.	☐	☐	☐
6. Service electrical system.			
a. Service battery.			
1) Clean battery, cable, terminals, and battery box.	☐	☐	☐
2) Tighten battery cables and battery hold-down.	☐	☐	☐
3) Check specific gravity of electrolyte and add water to proper level.	☐	☐	☐
4) Make high discharge or load test of battery condition.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
b. Service generator or alternator.			
1) Check belt tension.	☐	☐	☐
2) Test alternator or generator output.	☐	☐	☐
(NOTE: Refer to appropriate job sheet or engine service manual.)			
c. Service starting circuit.			
1) Check safety starter switch.	☐	☐	☐
2) Check current draw of starting motor.	☐	☐	☐

JOB SHEET #1

	Inspected	Serviced	Replaced
d. Service clutch free travel. Check free travel at clutch pedal or lever (if used). (NOTE: Refer to appropriate service manual.)	☐	☐	☐
7. Check engine performance by conducting a load test with a dynamometer. (NOTE: Refer to appropriate job sheet or dynamometer technical manual.)	☐	☐	☐

TUNE-UP AND ADJUSTMENT
UNIT III-D

JOB SHEET #2 — TUNE-UP A CUMMINS DIESEL ENGINE (TORQUE METHOD)

A. Tools and materials

1. Basic hand tool set
2. Cummins special tools
3. Torque wrench
4. Thickness gauge
5. Cleaning solvent
6. Diesel fuel
7. Shop towels
8. Safety glasses
9. Appropriate engine service manual

B. Procedure

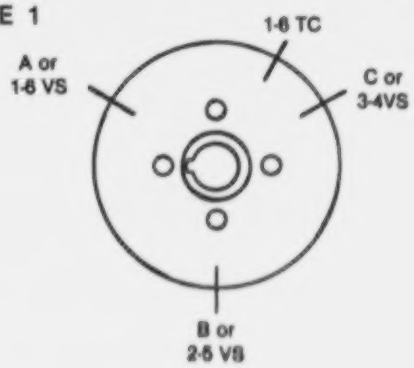
1. Adjust injector.
    a. Remove hood if applicable.
    b. Remove valve cover.

       (NOTE: Check the inside of the covers for presence of water condensation.)
    c. Loosen the injector rocker lever adjusting nut on all cylinders.

JOB SHEET #2

d. Rotate engine until the first "VS" mark on the pulley or damper is aligned with the index mark on the housing. (Figure 1)

FIGURE 1

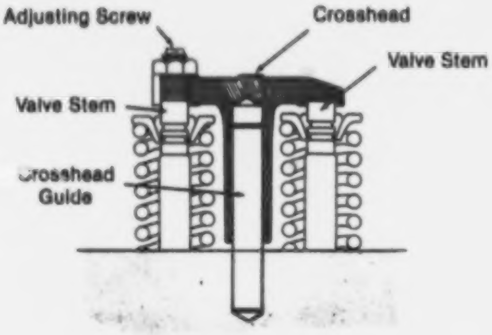

1-6 TC
A or 1-6 VS
C or 3-4VS
B or 2-5 VS

(Courtesy of Cummins Engine Company, Inc.)

e. Use an inch/lb torque wrench and in a near continuous motion draw the injector adjusting screw to its specified torque.

2. Adjust valve crosshead. (Figure 2)

FIGURE 2


Adjusting Screw
Crosshead
Valve Stem
Valve Stem
Crosshead Guide

(Courtesy of Cummins Engine Company, Inc.)

a. Loosen the adjusting screw lock-nut and back off the adjusting screw one turn.

b. Use light finger pressure at the rocker lever contact surface to hold crosshead in contact with the valve stem nearest the pushrod.

c. Turn adjusting screw down until it contacts its mating valve stem.

d. For new crosshead and guides, advance the adjusting screw 20° more to straighten the stem in its guide; a worn crosshead may be advanced 30° to straighten the stem in its guide.

JOB SHEET #2

e. Hold the adjusting screw in this position and tighten locknut to specified torque.

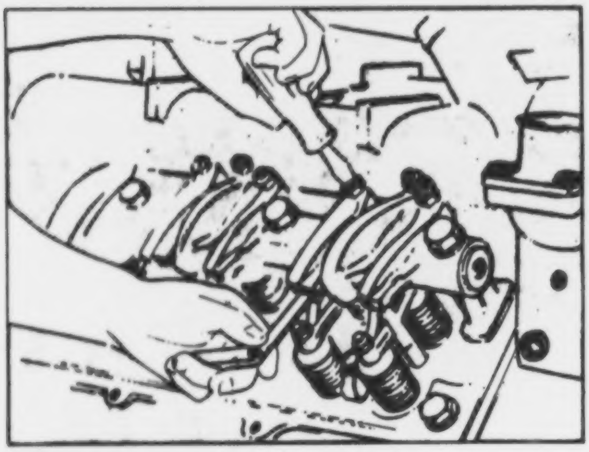
3. Adjust valve.

(NOTE: On engines equipped with compression release apparatus be sure that the shaft is fully released before adjusting valves.)

a. Loosen rocker arm locknuts.

b. Using a specified thickness gauge, turn the adjusting screw to obtain a good contact on the thickness gauge.(Figure 3)

FIGURE 3



(Courtesy of Cummins Engine Company, Inc.)

c. Adjust both the intake and exhaust valves.

d. Tighten locknuts.

e. Bar engine over in direction of rotation and firing order, and set the rest of the injectors, crossheads, and valves.

f. Install valve covers.

4. Check fuel pump filter screen.

a. Remove cap.

b. Lift screen out and inspect magnet for metal particles.

(NOTE: Large particles show excessive wear in gear pump.)

c. Clean screen.

d. Reinstall and torque to specified limits.

JOB SHEET #2

5. Adjust engine idle speed.
   a. Low idle.
      1) Attach tachometer to the drive outlet on top of the fuel pump.
      2) Remove pipe plug from spring pack cover.
      3) Set engine idle to manufacturer's specifications.

         (NOTE: Engine idle speed may change when the housing fills with fuel.)
   b. Adjust high idle.
      1) Attach tachometer to the drive outlet on top of the fuel pump.

         (NOTE: If high idle has to be changed, consult the appropriate shop manual or service bulletin.)
      2) Shut engine down.
      3) Remove spring pack cover.
      4) Remove snap ring.
      5) Increase or decrease shims to regulate engine speed; each .001 inch shim will increase or decrease engine speed by 2 rpm.

         (NOTE: Never set maximum speed to please an operator.)
   c. Check pump operation.
      1) Check manifold pressure.
         a) Install gauge at the shut-off valve.
         b) Operate engine 400 rpm below governed speed.
         c) Accelerate to governed speed.
         d) Observe gauge for specified pressure.
      2) Check inlet restriction.
         a) Install vacuum gauge at gear pump inlet.
         b) Operate warmed up engine 5 minutes after installation of gauge.
         c) Observe gauge readings.

            (NOTE: Readings should not exceed 8" to 8.5" vacuum.)

JOB SHEET #2

3) Check suction side, air leakage.

   a) Shut down engine.

   b) Install sight gauge on pump inlet side and operate engine.

   c) Check for air bubbles.

   (NOTE: Bubbles indicate an air leak.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

JOB SHEET #3 — TUNE-UP A CUMMINS DIESEL ENGINE (DIAL INDICATOR METHOD)

A. Tools and materials

1. Basic hand tool set
2. Cummins special tools
3. Torque wrench
4. Thickness gauge
5. Cleaning solvent
6. Diesel fuel
7. Shop towels
8. Safety glasses
9. Appropriate engine service manual

B. Procedure

1. Adjust injector using dial indicator.
    a. Remove hood if applicable.
    b. Remove valve cover.

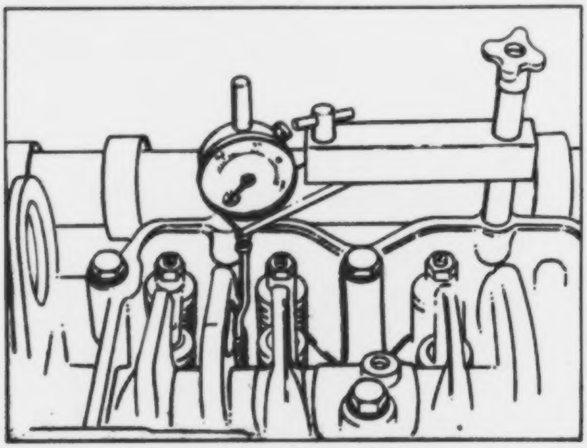
       (NOTE: Check the inside of the covers for presence of water condensation.)
    c. Loosen the injector rocker lever adjusting nut on all cylinders.
    d. Rotate engine until the first "VS" mark on the pulley or damper is aligned with the index mark on the housing.

       (NOTE: Exhaust valve should be closing on cylinder #6 when #1 cylinder is coming up on compression.)

JOB SHEET #3

e. Install the dial indicator on #1 injector. (Figure 1)

FIGURE 1

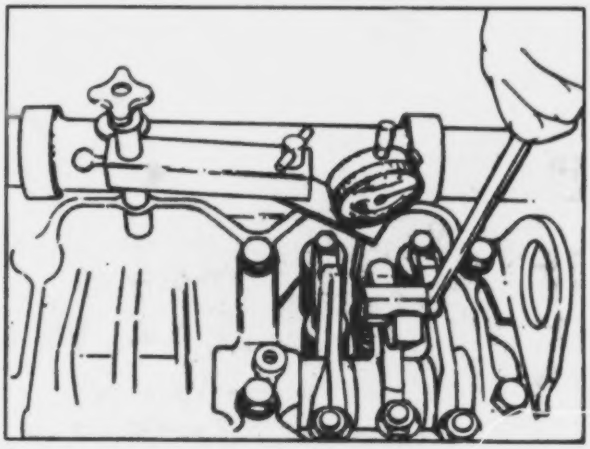


(Courtesy of Cummins Engine Company, Inc.)

(NOTE: Use injector adjustment kit, Part No. 3375842 or equivalent.)

f. Actuate injector rocker lever to bottom of travel two or three times. (Figure 2)

FIGURE 2



(Courtesy of Cummins Engine Company, Inc.)

JOB SHEET #3

g. Hold injector plunger at the bottom of its travel.

h. Zero the dial indicator.

i. Release actuator slowly.

j. Read travel on indicator.

k. Adjust to specifications if needed. (Tables 1 and 2)

Table 1.

Engine Firing Order	
Right Hand: 1-5-3-6-2-4	Left Hand: 1-4-2-6-3-5

Adjustment Limits
Using Dial Indicator Method — Inch [mm]

Oil Temp.	Injector Plunger Travel	Valve Clearance Intake	Valve Clearance Exhaust
Aluminum Rocker Housing			
Cold	0.170 ± 0.001 [4.32 ± 0.03]	0.011 [0.28]	0.023 [0.58]
Hot	0.170 ± 0.001 [4.32 ± 0.03]	0.011 [0.28]	0.023 [0.58]
Cast Iron Rocker Housing			
Cold	0.175 ± 0.001 [4.45 ± 0.03]	0.013 [0.33]	0.025 [0.64]
Hot	0.170 ± 0.001 [4.32 ± 0.03]	0.011 [0.28]	0.023 [0.58]
NTE-855 (European Big Cam Only)			
	0.225 [5.72]	0.011 [0.28]	0.023 [0.58]
NT-855 (Australian Big Cam Only)			
	0.228 [5.79]	0.011 [0.28]	0.023 [0.58]

Note: Always check the engine dataplate for the injector and valve adjustment values.

(Courtesy of Cummins Engine Company, Inc.)

JOB SHEET #3

Table 2.

Injector and Valve Set Position

Right Hand Rotation Engine

Bar in Direction	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A or 1-6 VS	3	5
Adv. To	B or 2-5 VS	6	3
Adv. To	C or 3-4 VS	2	6
Adv. To	A or 1-6 VS	4	2
Adv. To	B or 2-5 VS	1	4
Adv. To	C or 3-4 VS	5	1

Left Hand Rotation Engine

Bar in Direction	Pulley Position	Set Cylinder	
		Injector	Valve
Start	1-6 VS	2	4
Adv. To	3-4 VS	6	2
Adv. To	2-5 VS	3	6
Adv. To	1-6 VS	5	3
Adv. To	3-4 VS	1	5
Adv. To	2-5 VS	4	1

(Courtesy of Cummins Engine Company, Inc.)

(NOTE: Start on A or 1-6 VS but you must adjust injector #3 and valves on #5. See Table #2.)

JOB SHEET #3

- l. Bar engine to B or 2-5 VS.
- m. Adjust injector #6 and valves on #3.
- n. Continue until all injectors and valves are set.

2. Adjust valve crosshead.
   - a. Loosen the adjusting screw locknut and back off the adjusting screw one turn.
   - b. Use light finger pressure at the rocker lever contact surface to hold crosshead in contact with the valve stem nearest the push-rod.
   - c. Turn adjusting screw down until it contacts its mating valve stem.
   - d. For new crosshead and guides, advance the adjusting screw 20° more to straighten the stem in its guide; a worn crosshead may be advanced 30° to straighten the stem in its guide.
   - e. Hold the adjusting screw in this position and tighten locknut to specified torque.

3. Adjust valve.

   (NOTE: On engines equipped with compression release apparatus, be sure that the shaft is fully released before adjusting valves.)

   - a. Loosen rocker arm locknuts.
   - b. Using a specified thickness gauge, turn the adjusting screw to obtain a good contact on the thickness gauge.
   - c. Adjust both the intake and exhaust valves.
   - d. Tighten locknuts.
   - e. Bar engine over in direction of rotation and firing order, and set the rest of the injectors, crossheads, and valves.
   - f. Install valve covers.

4. Check fuel pump filter screen.
   - a. Remove cap.
   - b. Lift out screen and inspect magnet for metal particles.

     (NOTE: Large particles show excessive wear in gear pump.)

JOB SHEET #3

c. Clean screen.

d. Reinstall and torque to specified limits.

5. Adjust engine idle speed.

a. Adjust low idle.

1) Attach tachometer to the drive outlet on top of the fuel pump.

2) Remove pipe plug from spring pack cover.

3) Set engine idle to manufacturer's specifications.

(NOTE: Engine idle speed may change when the housing fills with fuel.)

b. Adjust high idle.

1) Attach tachometer to the drive outlet on top of the fuel pump.

(NOTE: If high idle has to be changed, consult the appropriate shop manual or service bulletin.)

2) Shut engine down.

3) Remove spring pack cover.

4) Remove snap ring.

5) Increase or decrease shims to regulate engine speed; each .001 inch shim will increase or decrease engine speed by 2 rpm.

(NOTE: Never set maximum speed to please an operator.)

c. Check pump operation.

1) Check manifold pressure.

a) Install gauge at the shut-off valve.

b) Operate engine 400 rpm below governed speed.

c) Accelerate to governed speed.

d) Observe gauge for specified pressure.

JOB SHEET #3

2) Check inlet restriction.
    - a) Install vacuum gauge at gear pump inlet.
    - b) Operate warmed up engine 5 minutes after installation of gauge.
    - c) Observe gauge readings.

      (NOTE: Readings should not exceed 8" to 8.5" vacuum.)

3) Check suction side, air leakage.
    - a) Shut down engine.
    - b) Install sight gauge on pump inlet side and operate engine.
    - c) Check for air bubbles.

      (NOTE: Bubbles indicate an air leak.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

JOB SHEET #4 — TUNE-UP A DETROIT DIESEL ENGINE

A. Tools and materials

1. Basic hand tool set
2. Cleaning solvent
3. GM diesel special tune-up tools
4. Torque wrench
5. Thickness gauge
6. Shop towels
7. Diesel fuel
8. Appropriate engine service manual
9. Safety glasses

B. Procedure

1. Adjust exhaust valve clearance.
    a. Adjust valves on cold engine.
        1) Remove loose dirt from valve rocker cover.
        2) Remove the cover.
        3) Place governor speed control lever in the idle speed position.
        4) Position engine by rotating the crankshaft until the injector follower is fully depressed on the cylinder to be adjusted.

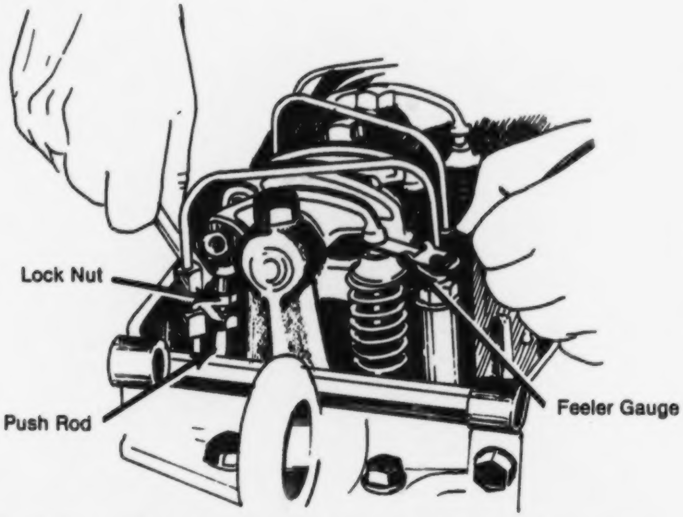
            (CAUTION: When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as the bolt will be loosened.)

        5) Loosen the exhaust valve rocker arm pushrod locknut.

JOB SHEET #4

6) Place a .013" feeler gauge between the valve stem and the valve rocker arm. (Figure 1)

FIGURE 1



7) Adjust the pushrod to obtain a smooth pull on feeler gauge.

8) Remove feeler gauge, hold the pushrod with a 5/16" wrench and tighten the locknut with a 1/2" wrench.

9) Recheck the clearance.

(NOTE: If the adjustment is correct, the .011" feeler gauge will pass freely between the valve stem and valve rocker arm, but the .013" feeler gauge will not pass through. This is referred to as "go-no go" measurement.)

10) Rotate engine in the direction of travel, and adjust remaining valves in same manner as above.

(CAUTION: Remove device used to bar engine before starting.)

b. Adjust valves on hot engine.

1) Start engine and bring to normal operating temperature (160-185°).

2) Recheck exhaust valve clearance with feeler gauge.

(NOTE: Valve clearance will decrease when engine is hot, therefore, "go-no go" clearance will be .008" and .010".)

JOB SHEET #4

3) Readjust the pushrod, if necessary.

4) Adjust and check the remaining exhaust valves in the same manner as above.

2. Time fuel injector.

(NOTE: Adjust the exhaust valve clearance before timing injectors.)

a. Place governor speed control lever in idle speed position.

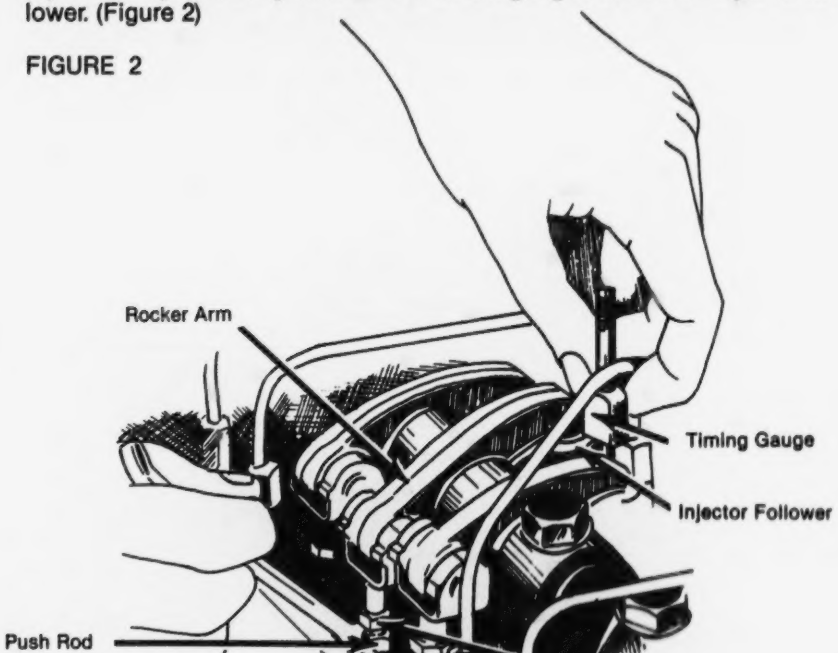
(NOTE: Secure stop lever in stop position, if used.)

b. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

(CAUTION: If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft on a left-hand direction rotation or the bolt may be loosened.)

c. Place the small end of the injector timing gauge in the hole provided in the top of the injector body with the flat of the gauge toward the injector follower. (Figure 2)

FIGURE 2



(NOTE: Refer to service manual for correct timing gauge and timing dimension for the injector being timed.)

JOB SHEET #4

d. Loosen the injector rocker arm pushrod locknut.

e. Turn the pushrod.

f. Adjust the injector rocker arm until the extended part of the gauge will just pass over the top of the injector follower.

g. Hold the pushrod.

h. Tighten the locknut.

(NOTE: Check the adjustment and, if necessary, readjust the pushrod.)

i. Time the remaining injectors in the same manner as outlined above.

j. Install the valve rocker cover, using a new gasket.

3. Adjust limiting speed mechanical governor and injector rack control.

(NOTE: These procedures should be completed after adjusting the exhaust valves and timing the fuel injectors.)

a. Adjust governor gap — Single weight governor.

1) Start engine and bring to operating temperature.

2) Stop engine.

3) Loosen the lever and disconnect the fuel modulator, the power control device, the load limiting device, or the air cylinder link, if the engine is so equipped.

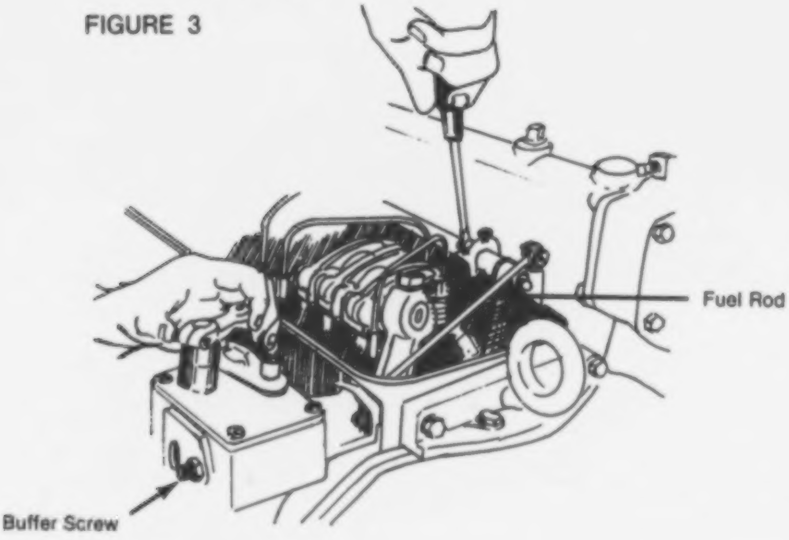
4) Remove the two attaching bolts.

5) Withdraw the governor high speed spring retaining cover.

JOB SHEET #4

6) Back out the buffer screw until it extends approximately $\frac{5}{8}$" from the locknut. (Figure 3)

FIGURE 3



7) Start the engine.

8) Loosen the idle speed adjusting screw locknut.

9) Adjust the idle screw to obtain the desired idle speed.

10) Hold the screw and tighten the locknut to retain the adjustment.

(NOTE: The recommended idle speed is 550 rpm for single weight governors, but may vary with special engine applications.)

11) Stop the engine.

12) Remove the governor cover and lever assembly.

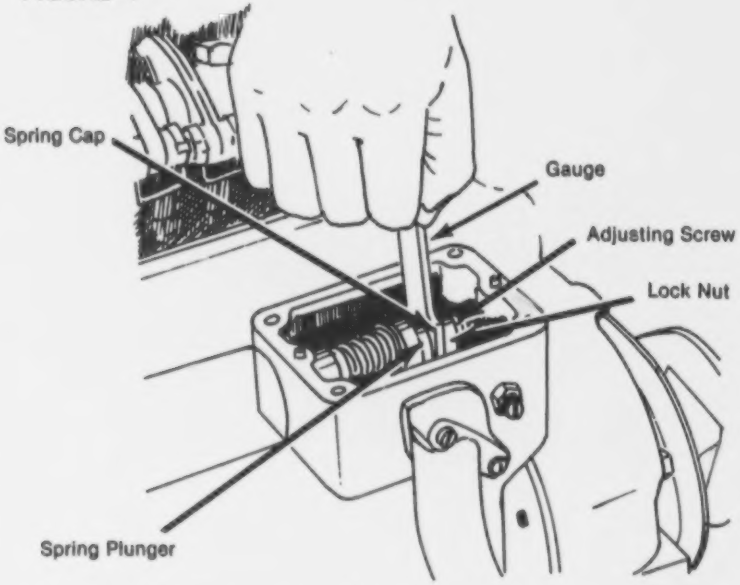
13) Clean and remove the valve rocker cover.

14) Remove the fuel rod from the differential lever and the injector control tube lever.

JOB SHEET #4

15) Check the gap between the low speed spring cap and the high speed spring plunger with gauge. (Figure 4)

FIGURE 4



16) Loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gauge, if required.

17) Hold the adjusting screw.

18) Tighten the locknut.

19) Recheck the gap and readjust if necessary.

20) Install the fuel rod between the governor and injector control tube lever.

21) Install the governor cover and lever assembly.

b. Adjust governor gap on a double weight governor.

1) Start engine.

2) Bring to operating temperature.

3) Stop engine.

4) Remove the two attaching bolts.

JOB SHEET #4

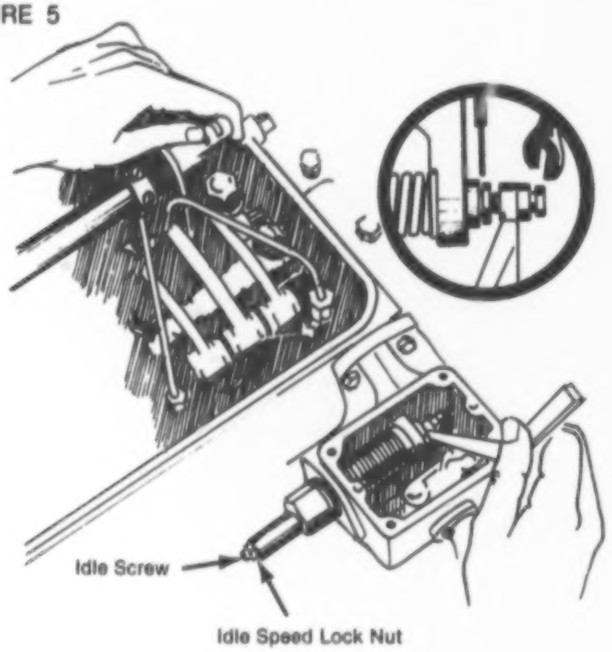
5) Withdraw the governor high speed spring retainer cover.

6) Back out the buffer screw until it extends approximately 5/8" from the locknut. (Figure 3)

7) Start the engine.

8) Loosen the idle speed adjusting screw locknut. (Figure 5)

FIGURE 5



9) Adjust the idle screw to obtain the desired idle speed.

10) Hold the screw and tighten the locknut to retain the adjustment.

(NOTE: The recommended idle speed is 450 rpm for double weight governors, but may vary with special engine applications.)

11) Stop the engine.

12) Remove the governor cover and lever assembly.

13) Clean and remove the valve rocker cover.

14) Remove the fuel rod from the differential lever and the injector control tube lever.

JOB SHEET #4

15) Start and run the engine between 800 and 1000 rpm by manual operation of the control tube lever.

    (CAUTION: Do not overspeed the engine.)

16) Check the gap between the low speed spring cap and the high speed plunger with a .0015" feeler gauge. (Figure 5)

    (NOTE: If the gap setting is incorrect, loosen the locknut and adjust the gap adjusting screw.)

17) Hold the gap adjusting screw.

18) Tighten the locknut.

19) Recheck the governor gap.

20) Stop the engine.

21) Install the fuel rod between the differential lever and the control tube lever.

22) Install the governor cover and lever assembly.

4. Position injector rack control levers.

   a. Disconnect any linkage attached to the governor speed control lever.

   b. Loosen the idle speed adjusting screw locknut.

   c. Back out the idle speed adjusting screw until 1/2" of the threads project from the locknut when the nut is against the high speed plunger.

   d. Loosen all of the inner and outer injector rack control lever adjusting screws.

      (NOTE: On engines equipped with a yield link type fuel rod, attach a small C-clamp at the shoulder of the rod to prevent the yield spring from compressing while adjusting the injector rack control levers.)

   e. Move the governor speed control lever to the full-fuel position.

   f. Hold the lever in that position with light finger pressure.

   g. Turn the inner adjusting screw on the no. 1 injector rack control lever down until a slight movement of the control tube is observed or a step up in effort is noted.

      (NOTE: This will place the no. 1 injector rack in the full-fuel position.)

JOB SHEET #4

h. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

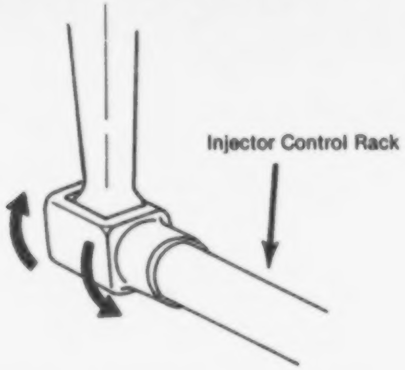
i. Alternately tighten both the inner and outer adjusting screws.

(CAUTION: Overtightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in-lbs.)

j. Hold the speed control lever in the full-fuel position.

k. Press down on the injector rack with a screwdriver or finger tip and note "rotating" movement of the injector control rack when the speed control lever is in the full-fuel position. (Figure 6)

FIGURE 6

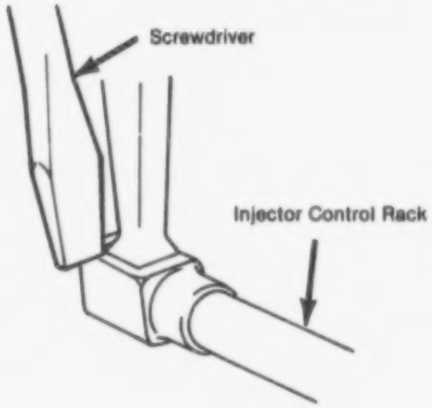


l. Hold the speed control lever in the full-fuel position.

m. Use a screwdriver to press downward on the injector control rack.

(NOTE: The rack should tilt downward and when the pressure of the screw is released, the control rack should "spring" back upward. See Figure 7)

FIGURE 7



JOB SHEET #4

n. Check to see if rack returns to its original position.

(NOTE: If it is too loose, back off the outer adjusting screw slightly and tighten the inner adjusting screw slightly. If too tight, back off the inner adjusting screw slightly and tighten the outer adjusting screw slightly.)

o. Disconnect the fuel rod from the injector control tube.

p. Hold the no. 1 injector in the full-fuel position.

q. Turn down the inner adjusting screw of the no. 2 injector until the injector rack has moved into the full-fuel position and the inner adjusting screw is bottomed on the injector control tube.

r. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

s. Alternately tighten both the inner and outer adjusting screws.

t. Recheck the no. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the no. 2 injector.

(NOTE: If the rack of the no. 1 injector has become loose, back off slightly on the inner adjusting screw on the no. 2 injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.)

u. Position the remaining injector rack control levers.

v. Connect the fuel rod to the injector control tube lever.

w. Turn the idle speed adjusting screw in until it projects ${}^{3}/_{16}$" from the locknut to permit starting the engine.

x. Tighten the locknut.

(NOTE: Remove the C-clamp from the fuel rod on units equipped with a yield link.)

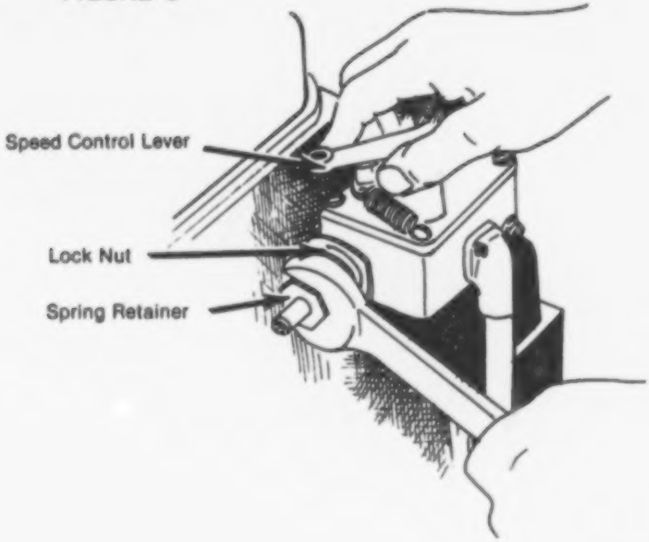
5. Adjust maximum no-load engine speed.

a. Loosen the locknut.

JOB SHEET #4

b. Back off the high speed spring retainer approximately five turns. (Figure 8)

FIGURE 8



c. Place the speed control lever in the full-fuel position with the engine at operating temperature and no-load on the engine.

d. Turn the high speed spring retainer in until the engine is operating at the recommended no-load speed.

e. Hold the high speed spring retainer.

f. Tighten the locknut.

6. Adjust idle speed.

   a. Remove the spring housing to uncover the idle speed adjusting screw.

   b. Turn the idle speed adjusting screw until the engine is operating at approximately 15 rpm below the recommended idle speed.

      (NOTE: The recommended idle speed is 550 rpm for single weight governors and 450 rpm for double weight governors, but may vary with engine applications.)

   c. Hold the idle screw.

   d. Tighten the locknut.

JOB SHEET #4

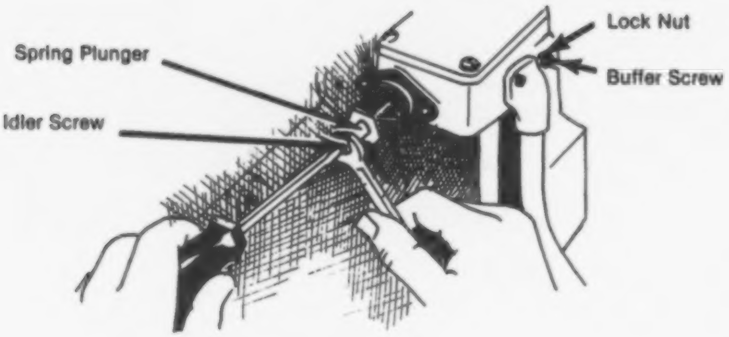
   e. Install the high speed spring retainer.

   f. Retain with the two bolts.

7. Adjust buffer screw.

   a. Turn the buffer screw in so that it contacts the differential lever as lightly as possible and still eliminates the engine roll. (Figure 9)

   FIGURE 9



   (NOTE: Do not increase the engine idle speed more than 15 rpm with the buffer screw.)

   b. Hold the buffer screw.

   c. Tighten the locknut.

   d. Recheck the maximum no-load speed.

   (NOTE: If it has increased more than 25 rpm, back off the buffer screw until the increase is less than 25 rpm.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

JOB SHEET #5 — TUNE-UP A 3400 SERIES CATERPILLAR DIESEL ENGINE

A. Tools and materials

1. Basic hand tool set
2. Caterpillar special tools
3. Appropriate engine service manual
4. Shop towels
5. Compressed air source
6. Feeler gauge
7. Safety glasses
8. Timing turning tool

B. Procedure

(CAUTION: Follow all shop safety procedures.)

1. Adjust valve lash.

   (NOTE: Engine should be run until it reaches normal operating temperature.)

   a. Stop the engine.

   b. Clean the top of the cylinder head and the base of the valve cover.

   c. Remove the brackets holding the lines to the instrument panel gauges. (Figure 1)

   FIGURE 1

Valve Cover

JOB SHEET #5

d. Remove the valve cover.

(NOTE: Keep dirt from falling inside the engine block or into the valve mechanism, as the valve cover is removed.)

e. Keep timing bolt in storage on flywheel housing; it can be installed in either the left side of the engine at location 1 (Figure 2) or in the right side of the engine at location 2 (Figure 3).

FIGURE 2

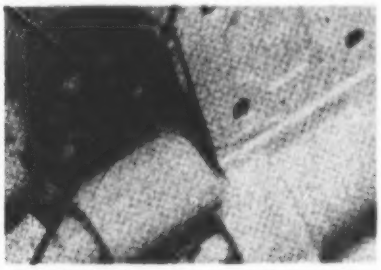

Timing Tool
Timing Tool Installed Left Side Location
Timing Tool Storage Location

FIGURE 3

Timing Tool Installed Right Side Location

(NOTE: No. 1 piston at top center (TC) on the compression stroke is the starting point of all timing procedures.)

f. Install engine turning tool into housing until shoulder of tool is against housing.

g. Attach a 1/2" drive ratchet to tool and turn flywheel while holding timing bolt in position in hole locations 1 or 2 where plug was removed. (Figure 4)

FIGURE 4

h. Stop rotation when timing bolt can be installed in threaded hole of flywheel.

JOB SHEET #5

i. Check to see if No. 1 piston is on the compression stroke; look at the valves of No. 1 cylinders, the valves will be closed if No. 1 cylinder is on the compression stroke.

j. Check the rocker arm; you should be able to move it up and down with your hand.

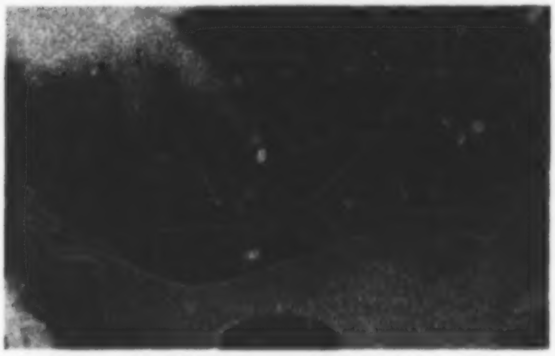
k. If No. 1 piston is not on the compression stroke turn the flywheel 360° and install the timing bolt.

2. Set bridge adjustment.

a. Loosen the locknut for the adjustment screw and loosen the adjustment screw several turns.

b. Put pressure on the bridge with a finger to keep the bridge in contact with the valve stem opposite the adjustment screw. (Figure 5)

FIGURE 5



c. Turn the adjustment screw clockwise until it makes contact with the valve stem.

d. Turn adjustment screw 30° more in a clockwise direction to make the bridge straight on the dowel, and to compensate for the clearance in the threads of the adjustment screw.

e. Hold the adjustment screw in this position and tighten the locknut to 22 lb. ft.

f. Put engine oil at the point where rocker arm makes contact with the bridge.

JOB SHEET #5

3. Set valve lash.

(NOTE: Valve clearance is measured between the rocker arm and the bridge for the valves. See Figure 6.)

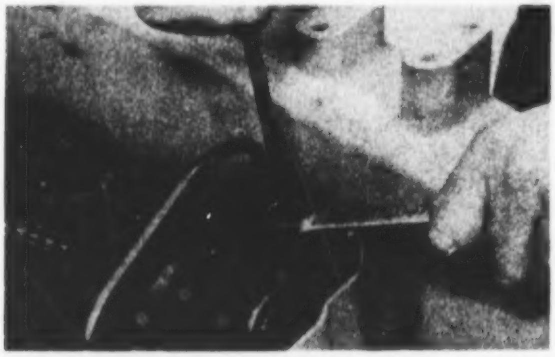
FIGURE 6

a. Put No. 1 piston at top center (TC) on the compression stroke, and loosen locknuts.

b. Make an adjustment to the valve clearance on the intake valves for cylinders 1, 2, and 4.

c. Make an adjustment to the valve clearance on the exhaust valves for cylinders 1, 3, and 5. (Figure 7)

FIGURE 7



d. Tighten the nut for the valve adjustment screw to 22 lb. ft. after each adjustment and recheck the adjustment.

e. Remove the timing bolt and turn the flywheel 360° in the direction of engine rotation. This will put No. 6 piston at top center (TC) on the compression stroke; install the timing bolt in the flywheel.

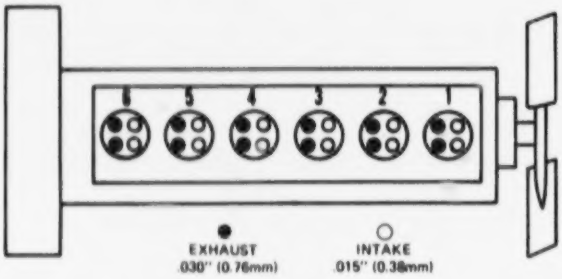
JOB SHEET #5

f. Make an adjustment to the valve clearance on the intake valves for cylinders 3, 5, and 6. (Figure 7)

g. Make an adjustment to the valve clearance on the exhaust valves for cylinders 2, 4, and 6.

h. Remove the timing bolt from the flywheel when all adjustments to the valve clearances have been made. (Figure 8)

FIGURE 8



Cylinder and Valve Location

4. Check valve rotation.

   a. Start the engine.

   b. Move the governor control to low idle position.

   c. Watch the serrations on each valve retainer.

   (NOTE: Each valve retainer should turn slightly each time the valve closes.)

   d. Stop the engine.

   e. Inspect the valve cover.

   f. Install a new gasket, if necessary.

   g. Install the valve cover.

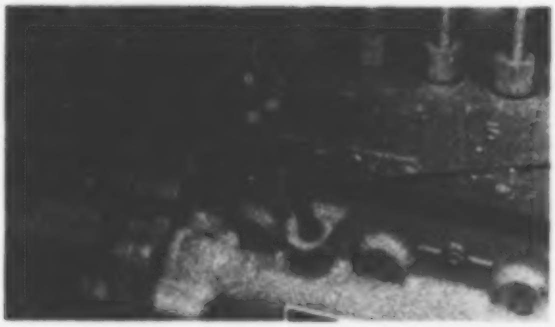
   h. Install the flywheel housing timing cover.

5. Check fuel injection pump timing.

   a. Install timing pin through the hole in the pump housing and into the notch in the camshaft. (Figure 9)

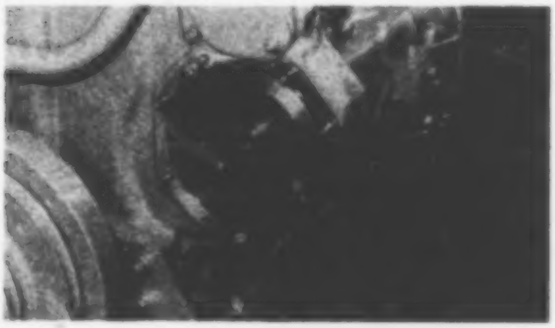
JOB SHEET #5

FIGURE 9



b. Loosen four bolts (one bolt on earlier engines) holding the automatic timing advance unit to the drive shaft for the fuel injection pump. (Figure 10)

FIGURE 10



c. Hit the automatic timing advance unit with a soft hammer to make it come loose from the end of the drive shaft for the fuel injection pump.

(NOTE: Be sure it will move freely on the end of the shaft.)

d. Put No. 1 piston at top center (TC) on the compression stroke.

e. Tighten the four bolts evenly to 25 lb. ft.; remove timing pin and tighten bolts evenly to 50 lb. ft.

f. Tighten bolts to a last torque of 100 lb. ft.

g. Remove the timing bolt from the flywheel.

h. Turn the crankshaft two complete revolutions, and check the timing again to see that timing is correct.

i. Check timing; if it is not correct, do the above procedure again.

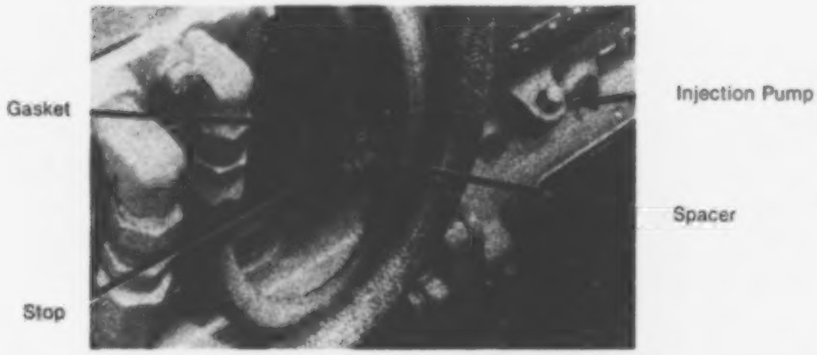
JOB SHEET #5

6. Set fuel rack, dial indicator, and circuit tester.

(NOTE: Always shut down the engine before adjusting rack setting.)

a. Remove stop, spacer, and both gaskets from the drive housing for the fuel injection pump. (Figure 11)

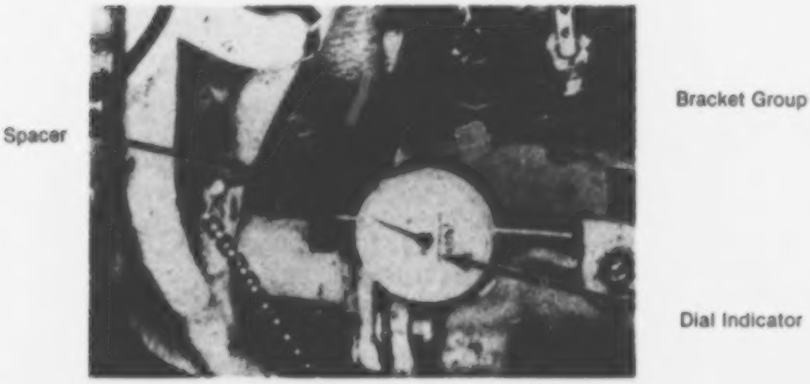
FIGURE 11


Gasket
Stop
Injection Pump
Spacer

b. Disconnect the governor control linkage to let the governor lever move freely through its full travel.

c. Install the bracket group and dial indicator on the drive housing for the fuel injection pump. (Figure 12)

FIGURE 12


Spacer
Bracket Group
Dial Indicator

d. Make sure the governor lever is in the "shut off" position, then put the spacer of the bracket group over the rod that makes contact with the rack.

JOB SHEET #5

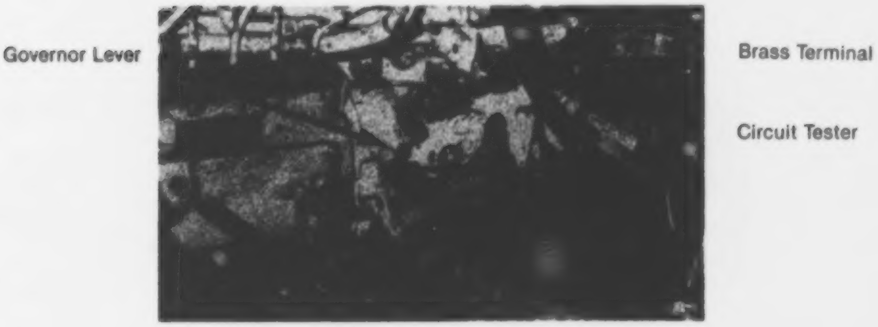
e. Put pressure on the end of the rod that makes contact with the rack to hold spacer in position while dial indicator setting is made.

f. Put the dial indicator on zero.

g. Remove the spacer from the rod that makes contact with the rack.

h. Connect the clip end of the circuit tester to the brass terminal on the governor housing. (Figure 13)

FIGURE 13


Governor Lever
Brass Terminal
Circuit Tester

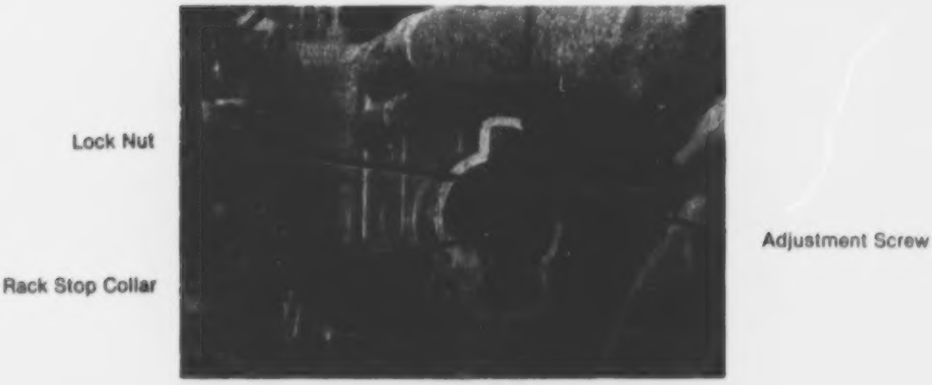
i. Put the other end of the tester to a good ground.

j. Turn governor lever (Figure 11) in the "fuel-on" direction until the light in the tester comes on.

k. Move the governor lever toward the "shut-off" position until the test light goes out.

l. Turn the governor lever slowly toward "fuel-on" until the test light has a minimum light output; in this position rack stop collar is just making contact with the torque spring or stop bar. (Figure 14)

FIGURE 14


Lock Nut
Rack Stop Collar
Adjustment Screw

JOB SHEET #5

m. Read the measurement on the dial indicator.

n. Check the rack setting information to find the correct measurement for rack setting.

o. Remove the cover, or air-fuel ratio control (if so equipped), from the rear of the governor if an adjustment is necessary.

p. Loosen locknut and turn adjustment screw to change the fuel rack setting if an adjustment to the fuel rack is necessary. (Figure 12)

q. Tighten locknut to 9 lb. ft. after the adjustment procedure is complete.

r. Install the cover or air-fuel ratio control (if so equipped).

7. Adjust governor.

(CAUTION: Only competent personnel should attempt to adjust the low and high idle rpm.)

(NOTE: Consult the appropriate service manual for the low and high idle rpm and rack setting dimension.)

a. Move the governor linkage to "low idle" position and turn screw to adjust the "low idle" rpm. (Figure 15)

FIGURE 15

High Idle Screw
Low Idle Screw
Cover

(NOTE: Engine rpm must be checked with an accurate tachometer.)

b. Increase the engine speed and then return linkage back to "low idle" position to check the setting again.

c. Move the governor linkage to "high idle" position and turn "high idle" screw to adjust "high idle" rpm.

JOB SHEET #5

d. Move the governor control to reduce engine speed, then move the linkage to "high idle" and check the setting again when the specific rpm setting is made.

e. Repeat this procedure until rpm setting is correct.

f. Install the cover on top of the governor when governor adjustment is correct.

g. Install a new wire and seal to cover bolt.

TUNE-UP AND ADJUSTMENT
UNIT III-D

PRACTICAL TEST
JOB SHEET #1 — TUNE-UP AND SERVICE A DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Serviced air intake and exhaust system.	______	______
3. Serviced basic engine.	______	______
4. Serviced fuel system.	______	______
5. Serviced lubrication system.	______	______
6. Serviced cooling system.	______	______
7. Serviced electrical system.	______	______
8. Serviced battery.	______	______
9. Serviced charging system.	______	______
10. Checked starting system.	______	______
11. Checked engine performance.	______	______
12. Checked in/put away tools and materials.	______	______
13. Cleaned the work area.	______	______
14. Used proper tools correctly.	______	______
15. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
16. Practiced safety rules throughout procedure.	______	______
17. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Serviced engine correctly	4	3	2	1
Engine performed properly	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

PRACTICAL TEST
JOB SHEET #2 — TUNE-UP A CUMMINS DIESEL ENGINE (TORQUE METHOD)

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted injectors.	______	______
3. Adjusted crossheads.	______	______
4. Adjusted valves.	______	______
5. Adjusted idle. (low and high)	______	______
6. Checked pump.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Engine performed properly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

PRACTICAL TEST
JOB SHEET #3 — TUNE-UP A CUMMINS DIESEL ENGINE (DIAL INDICATOR METHOD)

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted injectors.	______	______
3. Adjusted crossheads.	______	______
4. Adjusted valves.	______	______
5. Adjusted idle. (low and high)	______	______
6. Checked pump.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Engine performed properly				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

PRACTICAL TEST
JOB SHEET #4 — TUNE-UP A DETROIT DIESEL ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted valves.	______	______
3. Timed fuel injectors.	______	______
4. Adjusted governor.	______	______
5. Positioned injector control rack.	______	______
6. Adjusted maximum no-load speed.	______	______
7. Adjusted idle speed.	______	______
8. Adjusted buffer screw.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Engine performed properly				

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

PRACTICAL TEST
JOB SHEET #5 — TUNE-UP A 3400 SERIES CATERPILLAR ENGINE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Adjusted valve bridges.	______	______
3. Adjusted valves.	______	______
4. Checked valve rotators.	______	______
5. Checked pump timing.	______	______
6. Set fuel rack.	______	______
7. Adjusted governor.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #5 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Engine performed properly				

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TUNE-UP AND ADJUSTMENT
UNIT III-D

NAME ______________________ SCORE ____________________

TEST

1. Define terms related to tune-up and adjustment.
    a. Tune-up — ______________________________
    b. Service — ______________________________
    c. Replace — ______________________________
2. Complete the following list of major items to include in a visual inspection checklist.
    a. Oil and water leakage
    b. ______________________________
    c. Cooling system
    d. Air intake system
    e. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

3. Demonstrate the ability to:
    a. Tune-up and service a diesel engine. (Job Sheet #1)
    b. Tune-up a Cummins diesel engine (Torque Method). (Job Sheet #2)
    c. Tune-up a Cummins diesel engine (Dial Indicator Method). (Job Sheet #3)
    d. Tune-up a Detroit diesel engine. (Job Sheet #4)
    e. Tune-up a 3400 series Caterpillar diesel engine. (Job Sheet #5)

TUNE-UP AND ADJUSTMENT
UNIT III-D

ANSWERS TO TEST

1. a. Process of making checks and minor adjustments to improve the operation of the engine
   b. To clean, inspect, adjust, lubricate, or repair a component or part as needed
   c. To install a new or rebuilt component or part

2. b. Electrical system
   e. Fuel system

3. Performance skills evaluated to the satisfaction of the instructor